FINAL VERSION

Special Study Report

HYDROGEOLOGIC INVESTIGATION

For
Olin Chemicals Group
Wilmington, Massachusetts

February, 1982

MALCOLM PIRNIE, INC.
CONSULTING ENVIRONMENTAL ENGINEERS

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MALCOLM PIRNIE, INC.
ENVIRONMENTAL ENGINEERS, SCIENTISTS & PLANNERS

February 25, 1982

Mr. David Vaughn
Olin Chemicals Group
Environmental Affairs
Lower River Road
P.O. Box 248
Charleston, Tennessee 37310

Re: Olin Contract No. CS-WI-0000-01618
Hydrogeologic Investigation
Wilmington, Massachusetts

Dear Mr. Vaughn:

In accordance with the subject contract we are pleased to submit a final draft of our special study report entitled "Hydrogeologic Investigation" for the Wilmington plant.

The investigations indicate that the ground water and surface water regimes at the plant are complex. Also concentrations of inorganic and organic materials in the groundwater and surface water are quite variable.

Overall it appears that only the net discharges of ammonia and, to a lesser extent, the discharges of bis (2-ethyl hexyl) phthalate (DOP) and N-nitrosodiphenylamine are possible concerns relative to surface water quality.

Major source areas for these materials have been identified. A phased remediation program has been recommended for your review. The program identifies expeditious remedial actions already taken by Olin during this investigation, recommends further actions and outlines a monitoring program.

If you have any questions or require additional information, please do not hesitate to contact us.

Very truly yours,

MALCOLM PIRNIE, INC.

Richard P. Brownell

Richard P. Brownell, P.E.
Vice President

Steven P. Maslansky

Steven P. Maslansky, C.P.G.

RPB:hkh
enclosure

SUMMARY OF FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

1. The purpose of this report is to discuss the results of a hydrogeological investigation of the Wilmington site performed by Malcolm Pirnie, Inc. (Pirnie). The extent and movement of material in ground water and surface water will be discussed and a plan of remediation will be outlined.

2. The Olin site is underlain by crystalline bedrock of Precambrian to Carboniferous and possibly to Triassic age, Pleistocene glacial material, and Recent organic and man-made fill material.

3. The ground-water hydrology is governed to a large extent by the topography and the bedrock contours. The regional ground-water flow is generally towards the southeast and occurs mainly in the glacial material. In addition to recharge through the unsaturated zone, other sources of water for the ground water are the streams and the small pond, as well as man-made (cultural) contributions.

4. Ground-water discharge from the site is considered to be essentially constant. Overall it is indicated that between 71,000 gpd (April data) and 88,000 gpd (August data) was discharged from the site. Both of these estimates include discharge of water from the sludge lagoons (estimated at 8,000 to 10,000 gpd) and sewers and sumps (perhaps 2,000 to 4,000 gpd).

5. The net surface water discharge was measured to range between 0.21 and 0.32 mgd with a typical value of 0.22 mgd (81 MG per year). This is in the same range as the calculated total discharge estimated from ground-water flow and runoff.

6. On the basis of the contours of specific conductance, there appear to be two source areas for dissolved inorganic species on the site, the sludge disposal lagoons and nearby sumps and the area surrounding the storage tanks. From these two source areas, materials seem to migrate with the ground water, predominantly to the south and southeast, but with a localized discharge from the southwest of the lagoon area. There appears to be dispersion of the materials with migration.

7. A water budget analysis was used to determine that the sludge Lagoon 1 (see site map) was leaking. Lagoon 2 was not yet analyzed.

8. The effect of the Olin landfill on the ground water is considered to be minor.

9. During typical conditions in April (several days after a rain event), total site ground-water discharges were approximately 480 lbs/day of chloride, 2,065 lbs/day of sulfate, and 185 lbs/day of ammonia, as shown in Table IV-7. At the same time the total net load emitted from the site as gauged at SS-16 and SS-5 was 535 lbs/day of chloride, 930 lbs/day of sulfate, and 350 lbs/day of ammonia.

10. The major source of ammonia is believed to be leakage from the lagoons and related facilities. A secondary source is the area around the storage tanks and may be related to the leaking sewer repaired earlier in 1981. Ammonia moves along the predominant routes of ground-water flow. Volatiles (with concentrations above 0.05 mg/l) in the ground-water regime are bromoform, 1,2 dichloroethane, toluene, and methylene chloride. It appears that volatile concentrations in ground water drop off significantly a fairly short distance away from the areas of concentrations above 0.2 mg/l (storage tanks and lagoons).

11. Priority pollutant Volatiles were detected in the East Ditch with the highest concentrations entering the site at station SS-1 on the northern boundary of the site.

12. The Olin site is not believed to be the source of any volatile organic compounds in the surface water.

13. In regard to priority pollutant base/neutrals, roughly 0.1 to 2.5 lbs/day of DOP were calculated to be emitted from the ground water, while 0.15 to 5.0 lbs/day were measured leaving the site. A typical value appeared to have been 0.4 lbs/day. In regard to N-nitrosodiphenylamine a typical value leaving the site during the study appears to have been 0.01 lbs/day (as N-nitrosodiphenylamine).

14. There were no non-priority pollutant base/neutrals above detection limits. The only non-priority pollutant volatile that was detected was acetone, at 0.05 to 0.2 mg/l. The source was unkown.

15. The Olin site is discharging high amounts of three inorganic materials (ammonia, chlorides and sulfates) and low amounts of two organic priority pollutants (DOP and N-nitrosodiphenylamine). A significant portion of the organics discharge from the seep in the embankment along the East Ditch. All other inorganic and organic priority pollutants studied appear to be of no concern.

16. Of the inorganic and organic materials of possible concern discussed above, ammonia is considered to be of somewhat greater concern than the organics. It does not appear that even typical net chloride and sulfate discharges represent a significant water quality problem.

    The first phase of any remedial measures program should address reductions of ammonia. Reductions of chlorides and sulfates also are of some interest and are expected to be related to reductions in ammonia. The second phase of the program should address reductions in priority pollutant organics. The third phase would include monitoring to quantify the improvements obtained by earlier phases.

17. The lagoons are the most crucial area for application of remedial measures for ammonia. As discussed earlier, the lagoons are believed to be the largest single source of ammonia. They also are a major source of sulfate and chloride, and a minor source of a few organics. The primary remedial measure in the lagoon area is excavation of sludge and replacing the liners with a more secure liner system. These remedial measures have been completed for Lagoon 1.

18. Discharge of both organic and inorganic chemicals from the site, especially into the East Ditch, can be decreased by remedial measures in the storage tank area.

19. In order to obtain immediate reductions in contamination of water near the storage tanks, recovery well pumping has been initiated, and should be continued.

20. Considering the nature of the organics being discharged and all other factors, it was recommended that either a multiple recovery well system or an interception ditch be implemented. The multiple recovery well system has been implemented.

21. Because contaminants which have accumulated in and on the banks of the East ditch represent a substantial source of contaminants which may be readily transported off the site by stream flow, removal of this material is deemed an essential remedial measure.

22. The measures proposed above should reduce the discharge of materials from the Olin site. However, further monitoring of the ground and surface water should be done to document the efficiency of the remedial measures implemented and to determine if any further action appears warranted.

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The purpose of this report is to discuss the results of a hydrogeological investigation of the Wilmington site performed by Malcolm Pirnie, Inc. (Pirnie). The extent and movement of material in ground water and surface water will be discussed and a plan of remediation will be outlined.

II. GENERAL SITE DESCRIPTION

Location

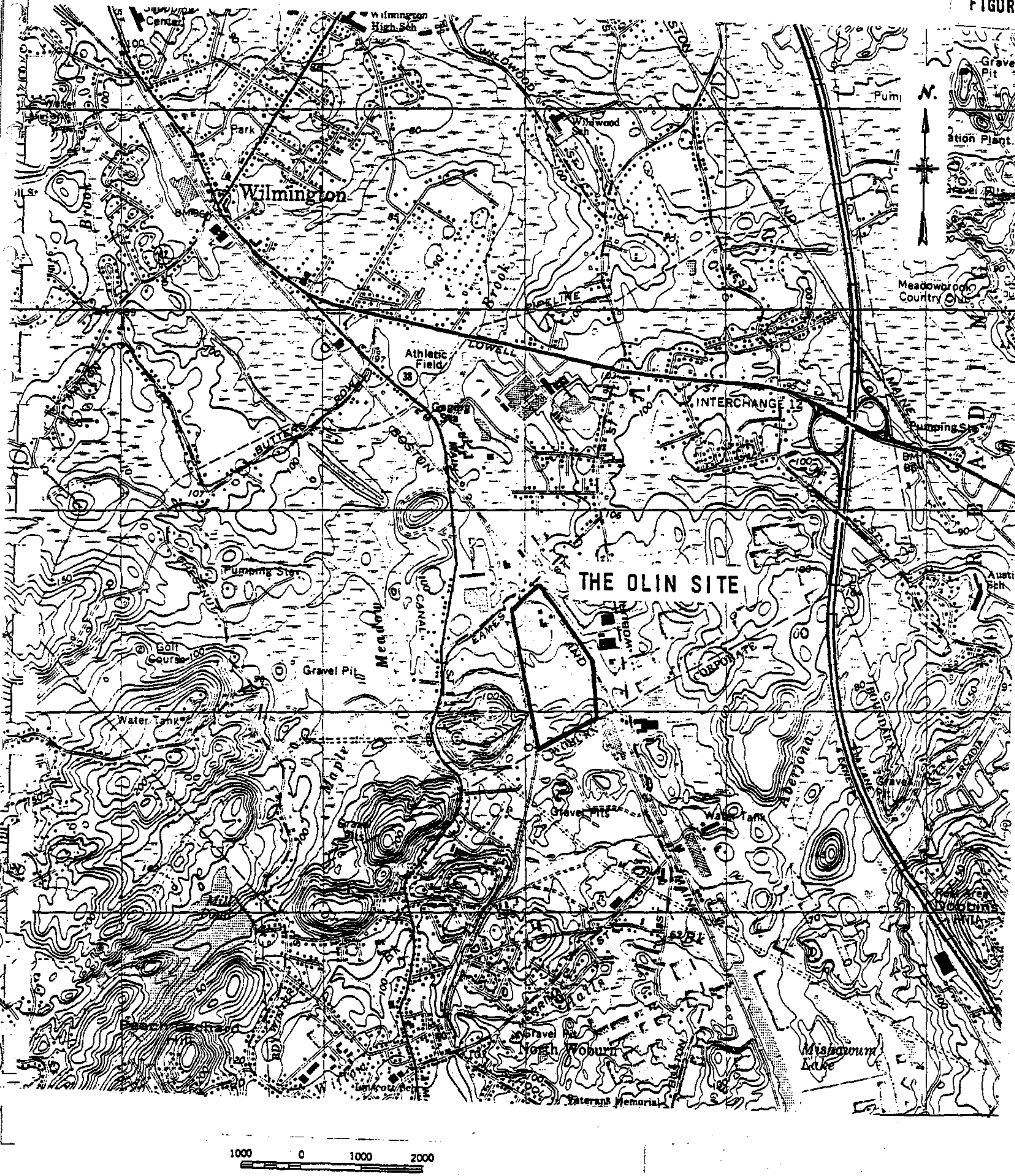
The Olin site is located in Wilmington, Massachusetts, shown on the USGS Wilmington Quadrangle map (7½ minutes) at approximately 42° 32' N. latitude and 71° 10' E. longitude. Figure II-1 shows the plant location. The site is approximately 49 acres and is bounded on the north by Eames Street, on the east and the west by the MBTA railroad tracks and to the south by the Wilmington-Woburn town line, beyond which lies the Woburn town refuse disposal area. The plant facilities are located in the northern part of the site and two lined sludge lagoons occupy the central portion; the southern half is wooded. Drainage ditches bound the site on the eastern and western edges; a third drainage complex bisects the site running west to east. Surrounding this drainage system is a low lying swampy area, with a small pond. The plant is located on a topographically high area which includes some filled area. The southern end of the site is also a topographic high. The plant landfill area for the calcium sulfate sludge is located on or near the southern boundary of the site.

Upstream to the north from the Olin site are several manufacturing plants. To the east of the MBTA railroad tracks is a drum reclaiming company. To the west is a roofing manufacturer and another chemical company. Also to the west is substantial tract of land (47 acres) which drains into the complex bisecting the Olin site from west to east.

Geology

The Olin site is underlain by crystalline bedrock of Precambrian to Carboniferous and possibly to Triassic age, Pleistocene glacial material, and Recent organic and man-made fill material. Figures II-2 through II-5 illustrate the geology of the site. The bedrock consists of gneissic rock

FIGURE



LOCATION OF WILMINGTON PLAN

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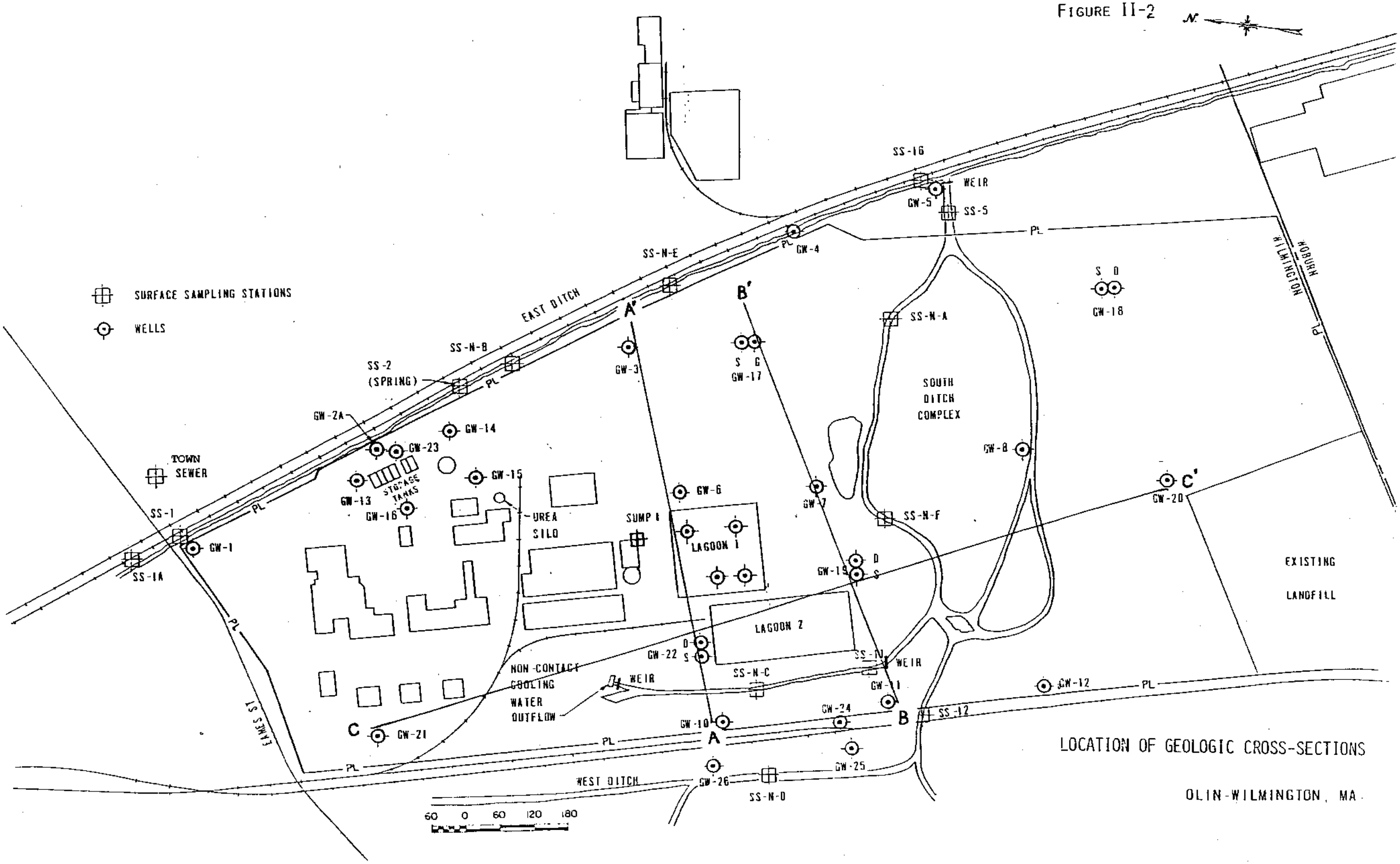
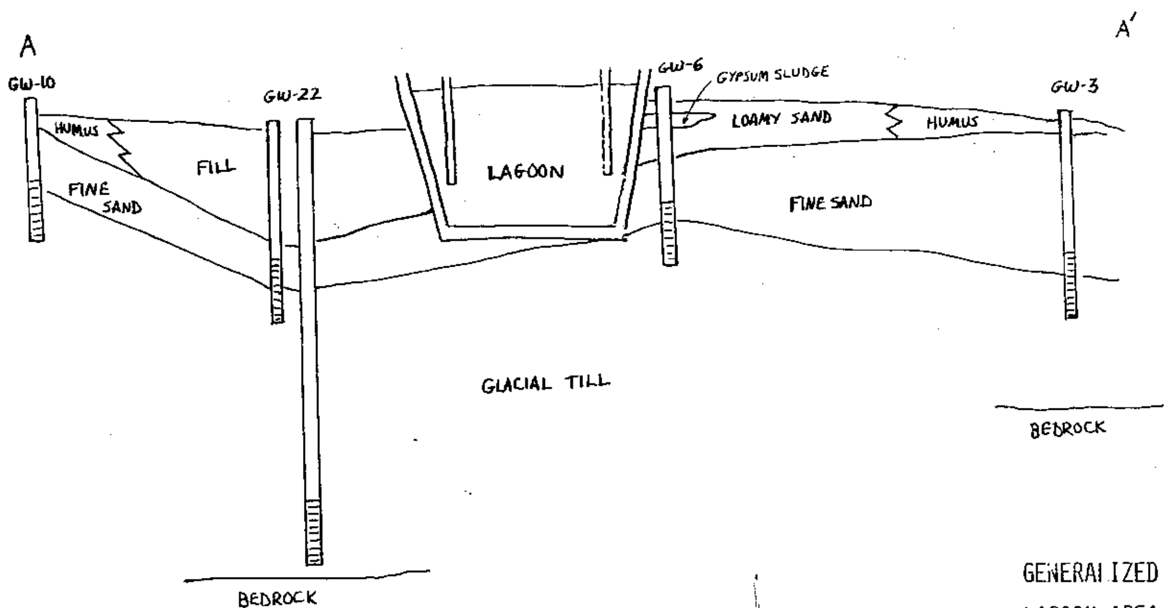
FIGURE II-2



LOCATION OF GEOLOGIC CROSS-SECTIONS

OLIN-WILMINGTON, MA

FIGURE II-3



GENERALIZED EAST-WEST CROSS-SECTION SHOWING LAGOON AREA, A-A'

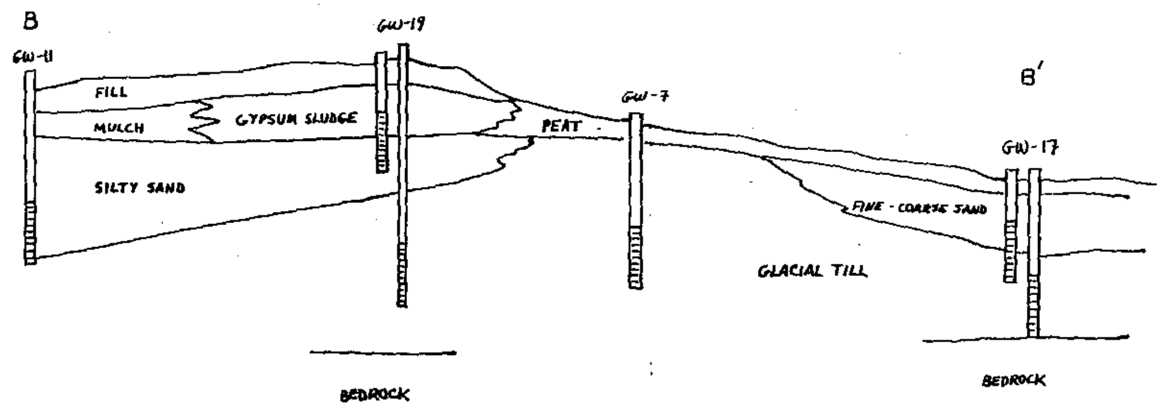
SCALES

HORIZONTAL: 1 INCH = 100 FEET

VERTICAL: 1 INCH = 10 FEET

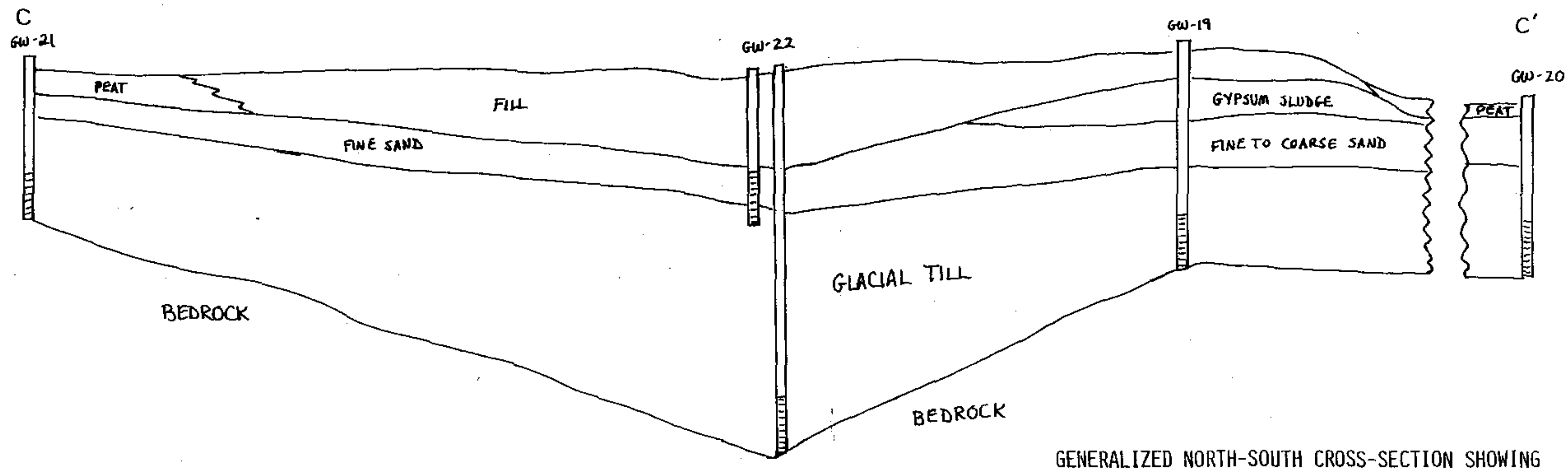
OLIN - WILMINGTON, MA.

FIGURE II-4



GENERALIZED EAST-WEST CROSS-SECTION
SHOWING SUBSURFACE GEOLOGY, B-B'
SCALE
HORIZONTAL: 1 INCH = 100 FEET
VERTICAL: 1 INCH = 10 FEET
OLIN-WILMINGTON, MA.

FIGURE II-5



GENERALIZED NORTH-SOUTH CROSS-SECTION SHOWING SUBSURFACE GEOLOGY, C-C′

SCALE

HORIZONTAL: 1 INCH = 100 FEET

VERTICAL: 1 INCH = 10 FEET

OLIN-WILMINGTON, MA.

with abundant quartz-infilled fractures. Outcrops occur in the northwest and southwest corners of the site and along the banks of the eastern drainage ditch. The outcrops appear to be somewhat fractured, with steeply dipping fracture planes. However, the borings conducted as part of this study showed the subsurface rock to be less fractured. (Boring procedures will be discussed in the next section). The borings also indicated the existence of a bedrock valley, possibly bisecting the site from the east to the west, in the central portion of the site. This bedrock valley appears to dip towards the west. Figure II-6 shows the bedrock contours.

The glacial material consists of unconsolidated material that can be divided into two subunits: till and outwash material.

The till overlies the gneissic bedrock and consists of unstratified, poorly sorted sands, silts and gravel with some large cobbles and boulders. Till is deposited by and directly under a glacier and is not reworked by meltwater streams.

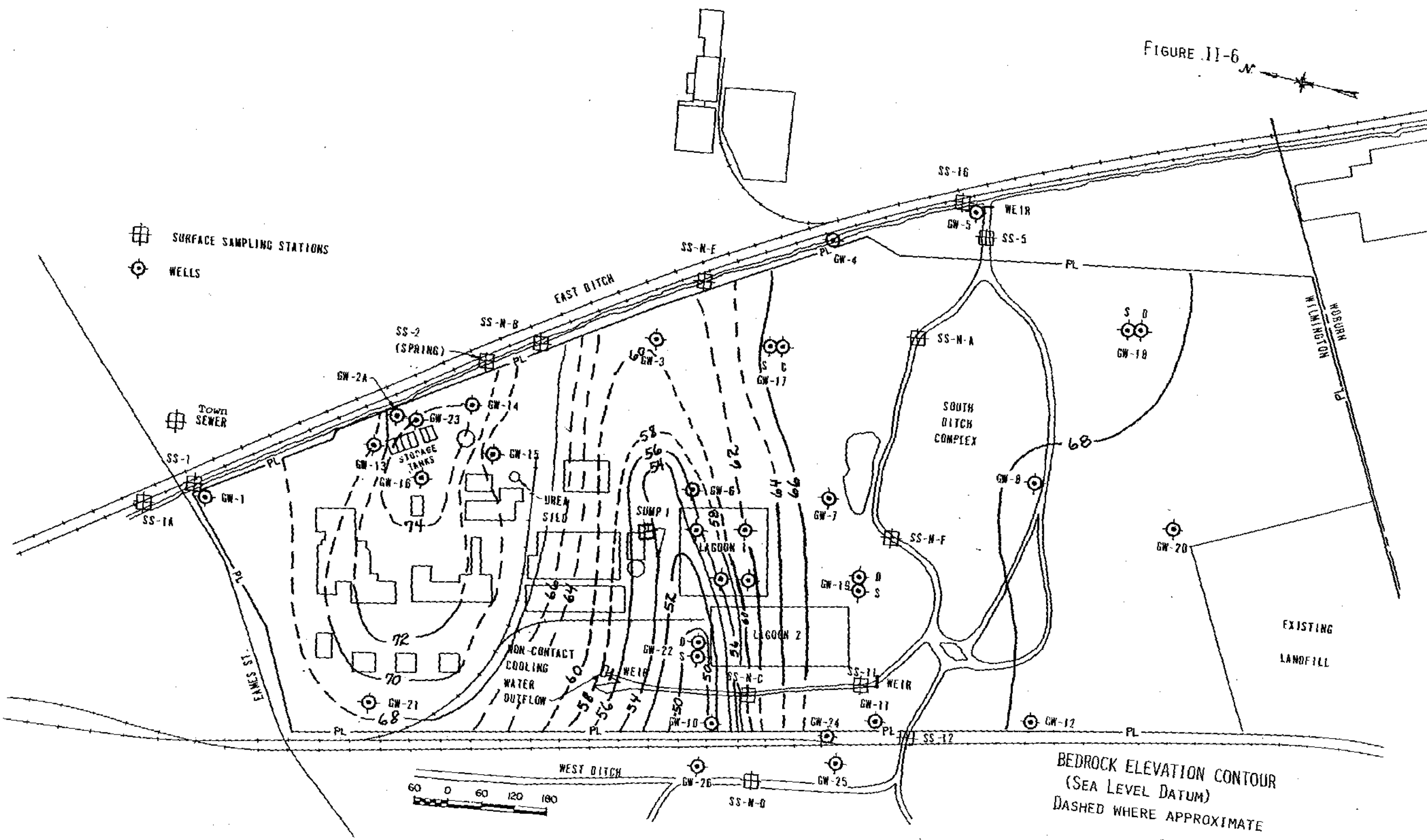
The outwash material overlies the till and is made of well to poorly graded sands and silts, with traces of gravel and clay. Outwash material is deposited at the edge of a melting glacier by meltwater streams.

The Recent surface organic layer overlies the outwash material, primarily in the low-lying areas of the site.

Local Hydrology

Surface water flow is controlled by the three major ditch systems: the East Ditch, the West Ditch and the South Ditch complex. (Please note that ditch designations used in this report differ from designations by others in earlier reports.) The East Ditch flows along the length of the site and contains water year-round due to flow from upstream. The only influent stream to the East Ditch is the South Ditch. The East Ditch also contains a spring (SS-2) which emanates from the stream bed. The fluid is golden-brown and appears to be emanating from the stream bed at a faster rate than the stream flow. The West Ditch also flows along the western boundary, turns east and becomes the beginning of the South Ditch. There are several small ephemeral influent streams from the western side of this ditch. The West Ditch becomes almost completely dry during the dry season. The South Ditch complex is actually a series of streams in a lowlying swampy area. In addition to the West Ditch, a source of water into the South Ditch is an intermittent non-contact cooling water outflow ditch which flows between the sludge lagoon and the western MBTA track. The South Ditch system becomes almost completely dry during the dry season. A small intermittent pond is also part of the South Ditch drainage system.

The ground-water hydrology is governed to a large extent by the topography and the bedrock contours. The regional ground-water flow is generally towards the southeast and occurs mainly in the glacial material. In addition to recharge through the unsaturated zone, other sources of water for the ground water are the streams and the small pond, as well as man-made contributions. This subject will be discussed in greater detail in Chapter IV.



BEDROCK ELEVATION CONTOUR
(SEA LEVEL DATUM)
DASHED WHERE APPROXIMATE

OLIN-WILMINGTON, MA.

III. INVESTIGATORY PROGRAM

Previous Investigations

In 1978, Geotechnical Engineers, Inc. (GEI) was contracted to undertake a ground-and surface-water study of the plant area by the Massachusetts Department of Environmental Quality Engineering. Twelve soil borings were performed and eleven monitoring wells were installed around the site to determine subsurface conditions. Ground-and surface-water samples were analyzed for selected organic and inorganic parameters.

In 1980, New England Pollution Control Company, Inc. (NEPCO) was requested by Olin to investigate the area on the eastern boundary of the site where black material was discharging out of the east bank. Eleven soil borings were made and five observation wells were installed. Samples of the black material were analyzed and ground-water measurements were made to determine direction of flow.

Present Investigation

This study program conducted by Pirnie over a one-year period during 1981 included both field and laboratory investigations and observations. The year was divided into four quarterly investigation periods. During the second quarter, the program was further split into three monthly investigation periods. The field work was performed by Pirnie personnel. The laboratory work was performed by the Pirnie laboratory in White Plains, New York and by Mead/CompuChem, Incorporated (CompuChem) in Research Triangle Park, North Carolina.

Field Work

The field investigation at the Olin site consisted of investigation of the geological material, the surface and ground water and the pertinent treatment and disposal facilities.

The geological material was investigated through two methods. Soil borings were performed and continuous soil samples were taken in order to determine characteristics of the subsurface material through laboratory analysis of moisture content, pH, cation exchange capacity and sieve-hydrometer grain-size distribution. Test pits were dug to further investigate the subsurface. Monitoring wells were also installed to investigate ground-water conditions.

Investigation of the surface-and ground-water conditions at the Olin site includes water level and flow measurements, field physiochemical analysis and water sampling, a total of 29 ground-water and 14 surface water sampling stations. Three samples each were also taken from the sewer system and the lagoons in order to define sources of contamination. Table III-1 lists the total sampling stations. Figure III-1 shows their locations.

- <u>Soil Boring and Monitoring Well Installation</u>. When Pirnie started investigations at the Wilmington site, there were 16 pre-existing monitoring wells on-site. In order to provide a more comprehensive sampling grid and obtain more information on the subsurface, six new well sites were constructed with a total of ten new monitoring wells. Four of these six well areas consist of a nested well system, which contain two monitoring wells (one shallow and one deep) located next to each other. A large-diameter well was also constructed near the northeast storage tanks for general observation. Well GW-2, after being destroyed by a backhoe, was replaced before the August sampling period. The new well was designated GW-2A. An additional monitoring well, GW-23, was installed near the storage tanks at the same time. Three drive-point monitoring wells, GW-24, GW-25, and GW-26, were also installed near the west ditch before the August sampling.

TABLE III - 1

SAMPLING STATIONS - OLIN - WILIMINGTON

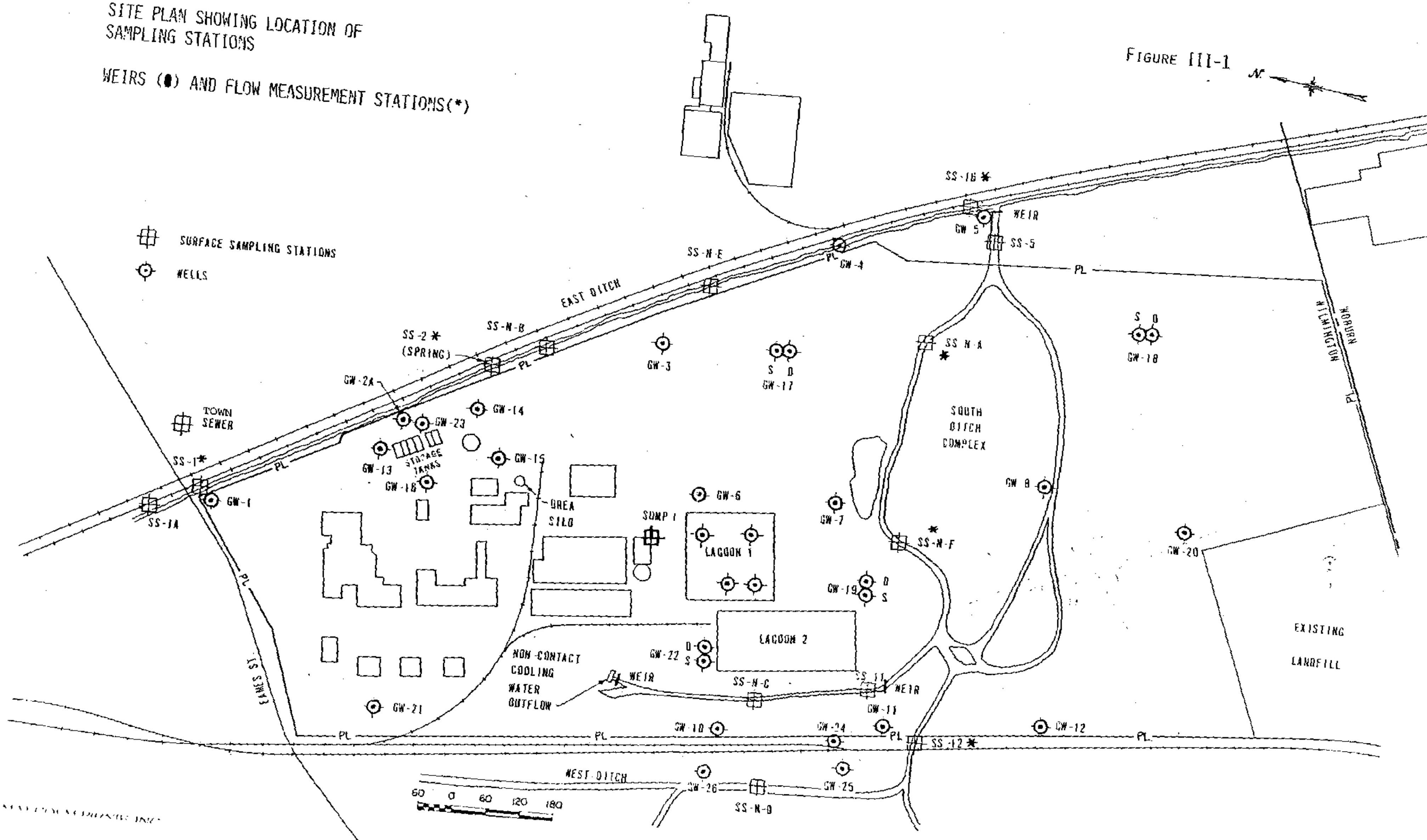
Ground Water	Surface Water	Sewer	Lagoons
GW-1	SS-1	SUMP 1	LAGOON 1(SOLID)
GW-2 + 2A	SS-1A	TOWN SEWER	LAGOON 1(LIQUID)
GW-3	SS-2(SPRING)	PLANT SEWER	LAGOON 2(LIQUID)
GW-4	SS-5		
GW-5	SS-11		
GW-6	SS-12		
GW-7	SS-16		
GW-8	SS-N-A		
GW-10	SS-N-B		
GW-11	SS-N-C		
GW-12	SS-N-D		
GW-13	SS-N-E		
GW-14	SS-N-F		
GW-15	SS-N-G		
GW-16			
GW-17S*			
GW-17D**			
GW-18S			
GW-18D			
GW-19S			
GW-19D			
GW-20			
GW-21			
GW-22S			
GW-22D			
GW-23			
GW-24			
GW-25			
GW-26			
Recovery Well - 1			

* S = Shallow
** D = Deep

SITE PLAN SHOWING LOCATION OF SAMPLING STATIONS

WEIRS (●) AND FLOW MEASUREMENT STATIONS(*)

FIGURE III-1



OLIN-WILMINGTON, MA.

o Test Pits. Test pits were dug in March 1981 and August 1981 around the northeast storage tanks to further assess the subsurface material, to install a recovery well, and specifically to delineate the extent of contaminant movement around the tank area. The test pits were dug using a backhoe provided by George Gately, of Wilmington, Massachusetts. Two test pits were dug in March, 1981. Four test pits were excavated during the August, 1981 period.

o Water Measurements. Ground-water level measurements were taken at each investigation period during the four quarters, totalling six measurements for the year. The measurements were taken using a drop light. Ground water elevations were then calculated, and potentiometric maps of the ground-water table were drawn.

Surface-water flow velocity measurements were made either with a Marsh-McBirney flow meter or a weir. Cross-sectional measurements of the stream were taken at each flow measurement station in order to calculate stream discharges. Two weirs were contructed by Pirnie personnel in order to measure stream flow more precisely. One weir was constructed in the South Ditch near its confluence with the East Ditch. The other weir was built downstream of the non-contact cooling water effluent pipe. Figure III-1 shows the location of the weirs and flow measurement stations.

o Physiochemical Measurements. The field physiochemical measurements made were pH, temperature, specific conductance and dissolved oxygen (D.O.). Table III-2 shows the schedule of measurements. Measuring techniques and types of equipment used are listed in Appendix A.

These field physiochemical measurements (except the D.O.) were performed at the major surface and ground-water sampling stations, (designated SS and GW, respectively) for all of the sampling periods. The D.O. was taken during one sampling period only, to ascertain whether the geochemical system was operating under aerobic or anaerobic conditions.

o Well and Surface Water Sampling Techniques. Sampling was performed using two methods, a PVC bailer for the ground-water samples and by dipping the sample bottles to obtain surface water samples. The order of sampling was from less contaminated to more contaminated stations, in order to lessen any possibility of cross-contamination of samples.

To obtain the ground-water samples, the total volume of the wells was evacuated three times before sampling, with a 1½-inch PVC bailer. Samples were also obtained by use of the bailer. For sampling volatiles care was taken not to agitate the ground water while sampling. The bailer was rinsed with distilled water after each well sampling was completed. The bailer was rinsed with acetone, then distilled water after sampling wells with high levels of organic contaminants.

Surface water sampling was performed by dipping the sample bottle below the stream surface, in order to obtain a more representative sample from the stream flow.

o Lagoon Monitoring. The two sludge lagoons were also monitored through sampling and water level measurements. In order to monitor Lagoon 1, the smaller 195 ft. by 195 ft. lagoon, four one-inch diameter well points were installed in the lagoon. Water levels were taken during the first, second and third quarters, for a total of five measurements. Reconstruction of the lagoon prevented measurements from being taken in the fourth quarter. The water levels were used to calculate a water balance for the lagoon, described in a later portion of this report. One sample each of the Lagoon 1 liquid and solids, and the Lagoon 2 (260 ft x 85 ft) liquid was taken in the third quarter. Field pH measurements were taken in each of the three quarters.

Laboratory Soil Tests

Laboratory tests were performed in the Pirnie soils laboratory on selected soil samples from the borings. The laboratory tests performed included moisture content, cation exchange capacity (CEC), sieve-hydrometer grain-size distribution analysis, and pH measurements. These tests were performed according to the procedures and methods listed in Appendix B.

Laboratory Chemical Analysis

Water samples were analyzed for selected inorganic constituents, Priority Pollutant volatile and base/neutral constituents and non-Priority Pollutant organic constituents during the course of the year. Table III-2 shows the schedule of analysis for the chemical constituents.

The analyses of the inorganic constituents and selected volatile Priority Pollutants during certain sampling periods was performed by Pirnie. The analysis of the majority of the volatile and base/neutral Priority Pollutant constituents as well as the non-Priority Pollutant constituents was performed by CompuChem.

The techniques used for the analysis of the inorganic constituents are listed in Appendix C. The techniques used for the organic analysis are listed in Appendix E.

TABLE III - 2

Constituent	1st Qtr.	2nd Qtr.			3rd Qtr.	4th Qtr.
	3-81	4-81	5-81	6-81	8-81	12-81
Field						
1. pH	*	*	*	*	*	*
2. Specific Conductance	*	*	*	*	*	*
3. Temperature	*	*	*	*	*	*
4. Dissolved Oxygen		*	*	*		
Laboratory						
1. Chlorides	*	*	*	*	*	*
2. Sulfates	*	*	*	*	*	*
3. Ammonia	*	*	*	*	*	*
4. Nitrate-Nitrite	*	*	*	*	*	*
5. Alkalinity	*	*	*	*		*
6. Metals:						
Lead	*	*	*	*	*	*
Chromium Total	*	*	*	*	*	*
Cr^{+3}, Cr^{+6}		*	*	*	*	*
Cadmium	*	*	*	*	*	*
7. Volatile Priority Pollutants	*		*		*	*
8. Base-Neutral Priority Pollutants	*		*		*	*
9. Non-priority Pollutants						
dioctyldiphenylamine	*					
20 peak search			*		*	

CHAPTER IV
DATA EVALUATION

General

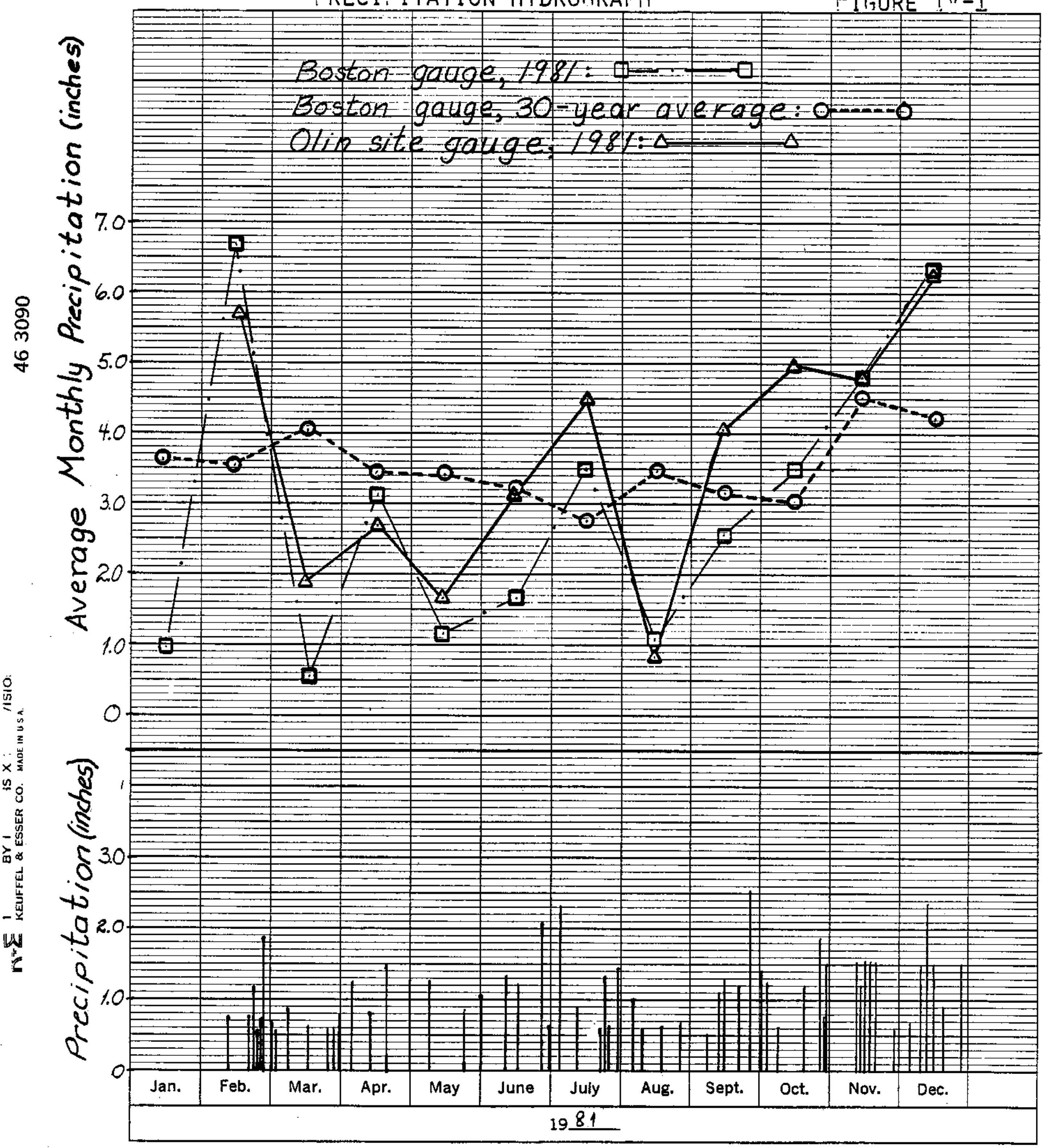
As discussed in previous sections, an extensive field and laboratory investigatory program was undertaken to determine the extent of materials on the Olin site and the movement of materials onto and off the site. To accomplish this objective, field information was collected to quantify precipitation and ground-water and surface water flows to and from the site. Consideration was given to both naturally and culturally induced water flows and also to the possibility of seasonal differences.

The water balance information was then to be interfaced with data on inorganic and organic materials in the ground and surface waters. It was expected that approximate material balances could be obtained on materials of interest. This in turn would facilitate the evaluation of any appropriate remedial measures.

As a first step, a comparison was made of total monthly precipitation measured with the gauge at the Olin site, the gauge in Boston, and the thirty-year average total monthly precipitation measured. Figure IV-1 indicates that 1981 was a slightly below average water year. The total annual precipitation based on the thirty-year average data was 40.5 inches per year versus about 37 inches per year in 1981 at Olin. Figure IV-1 also indicates that March, November and December historically are high rainfall months while July is the lowest. March also was considered by Pirnie to be a historically possible high surface water month, as a result of snow melt. However, the Olin site received subnormal precipitation in March (normally wet). Data from the Boston station also indicates that January was a dry month while February received higher-than-average rainfall. While July was wetter than

PRECIPITATION HYDROGRAPH

FIGURE IV-1



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normal, August was a very dry month. While the thirty-year average data indicate that there is a mild seasonality in precipitation in the area, the 1981 data from both the Boston and the Olin gauges indicate that specific precipitation events can completely mask the mild, long-term trends.

The ground-water system will generally have a slow response time to additions of precipitation (weeks to several months) but will generally reflect cumulative precipitation events over the last several months. Surface water responds to precipitation events in a shorter time (several hours to 36 hours); hence the surface runoff measurements made at a point in time on the Olin site also reflect a response to recent discrete precipitation events. The differences in response times between these two systems complicates interpretation of surface and ground-water data at this site. Overall the precipitation data indicate that there are no seasons of significance, only dry and wet periods of varying time duration. Consideration will be given to using average annual discharges where appropriate. Ground-water and surface water discharge data are discussed below with this in mind.

Ground-Water Flows

Hydraulic Conductivity

As discussed earlier, there are two principal subunits in the unconsolidated sediments underlying the site: the sand and the glacial till. These have differences in their hydrogeologic properties which are discernible by both field descriptions and laboratory investigations.

Field descriptions from borings completed on the site delineated the thickness and areal extent of the two soil subunits. Grain size analysis by sieve and hydrometer methods were performed to verify field descriptions and to determine the hydraulic conductivities of the soils underlying the Olin site. Laboratory estimates of hydraulic conductivity varied from 34 ft/day ($1.2x10^{-2}$ cm/sec) to 0.2 ft/day ($7.2x10^{-5}$ cm/sec). These values were in the same range (57 ft/day ($2x10^{-2}$ cm/sec) to 0.3 ft/day ($1x10^{-4}$ cm/sec) as those determined by Geotechnical Engineers Incorporated (GEI) by in-situ falling head tests in wells set in the soils in the Olin site. A table in Appendix B summarizes the measured hydraulic conductivities which vary both between and within soil types. However, the site soils are quite variable. This complexity makes it extremely difficult to estimate ground-water flows except in using average hydraulic conductivity for the site. An average of 17 ft/day ($6x10^{-3}$ cm/sec) was used to calculate discharge.

Ground-Water Table

The water levels measured in the monitoring wells were expected to be useful for two purposes: identification of recharge and discharge areas; and, the estimation of overall ground-water flow velocities and flows. To develop the overall ground-water flows, well water levels observed during all six field trips were reviewed. Water contour maps were drawn for April and August (Figures IV-2 and IV-3).

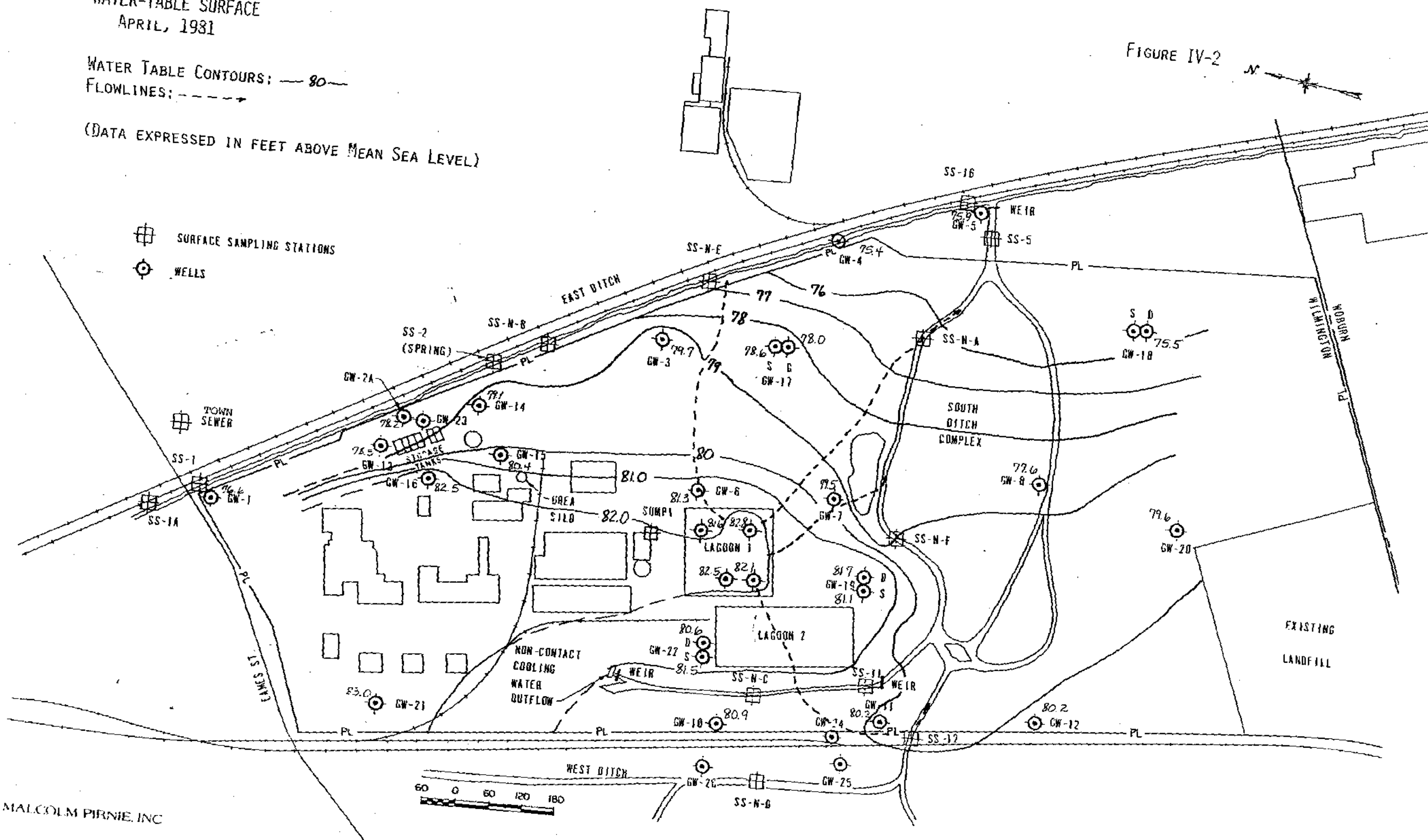
Nested wells assisted in differentiating recharge zones (where head in the shallow well is greater than head in the deep well) from discharge zones (where head in the shallow well is less than head in the deep well). The area near GW-19 (between the lagoons and the South Ditch complex) is a ground-water discharge zone at all sampling times while the areas around the other nested wells were ground-water recharge zones. The upward flow of ground water in the area around GW-19 signifies two things: first, all of the ground water discharged from the site toward the South Ditch complex should discharge into the Ditch (i.e., ground water does not bypass the Ditch by flowing under the Ditch), second, symmetrical discharge of ground water from the soils south of the South

WATER-TABLE SURFACE
APRIL, 1981

WATER TABLE CONTOURS: —80—
FLOWLINES: - - - - →

(DATA EXPRESSED IN FEET ABOVE MEAN SEA LEVEL)

FIGURE IV-2



MALCOLM PIRNIE, INC

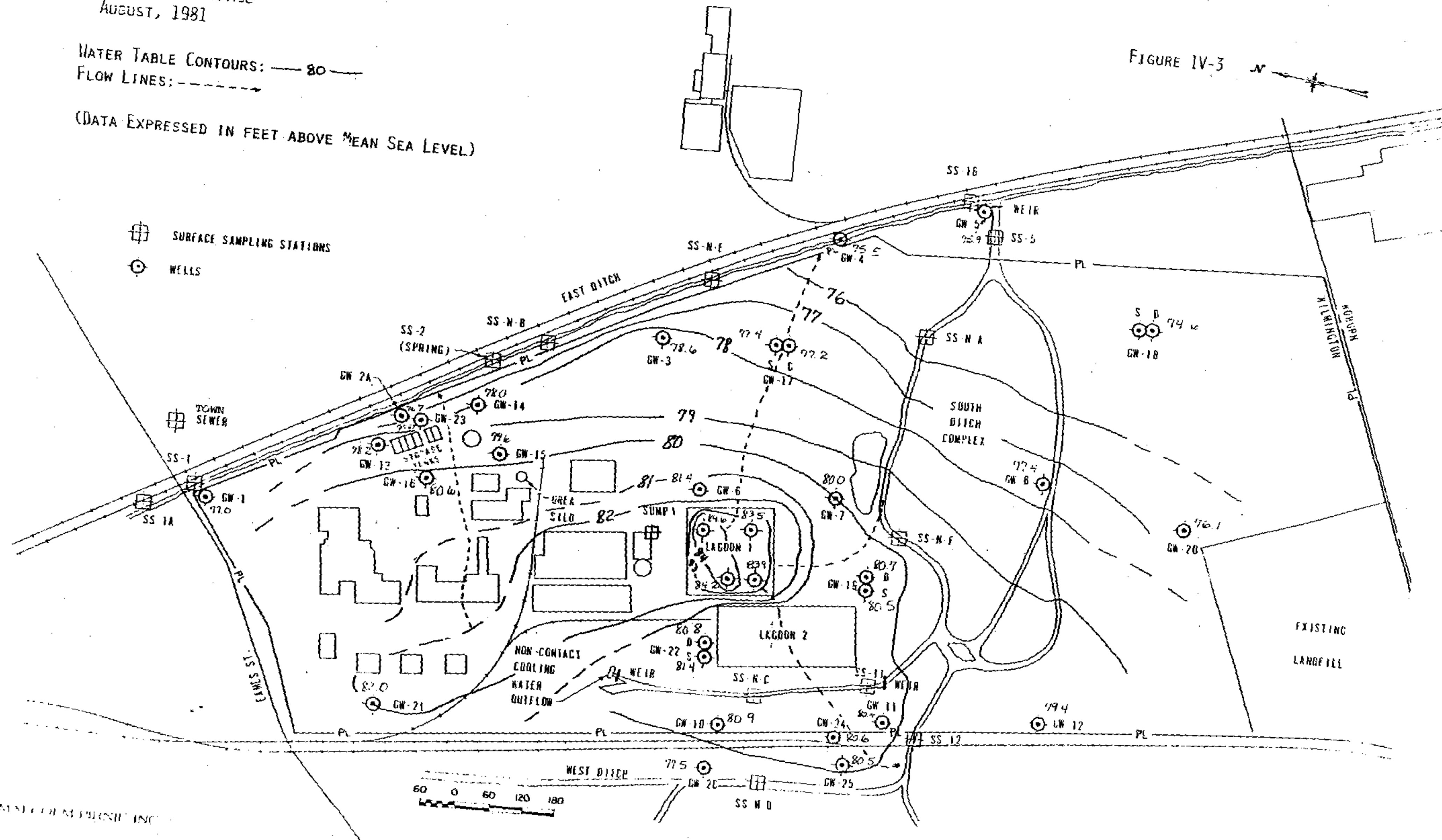
OLIN-WILMINGTON, MA.

WATER TABLE SURFACE
AUGUST, 1981

WATER TABLE CONTOURS: —— 80 ——
FLOW LINES: - - - - - - - ->

(DATA EXPRESSED IN FEET ABOVE MEAN SEA LEVEL)

FIGURE IV-3



OLIN WILMINGTON, MA.

Ditch complex is a reasonable assumption. The contours shown (graduated in feet above sea level datum) connect points of equal hydrologic head (potential). As indicated by the dashed lines in Figure IV-2, ground-water flow is almost always perpendicular to these contour lines at any one point in time. Therefore, the dashed lines illustrate the direction of ground-water flow on the site. Throughout the Olin site, there is a general south-southeast decrease in elevation of the ground-water table (gradient) which is probably the natural flow direction produced by bedrock configuration and location of recharge areas. A north-south trending ground-water mound is superimposed on this natural gradient in the area which underlies Lagoon 1 and the buildings to the north of Lagoon 1. This mound is probably influenced by man-made inputs. Leakage from the lagoons probably contributes to the south end of the mound. Ground water recharge by roof or foundation drains from the buildings and possibly leakage from sewer lines also represent a minor contribution; however, this was not investigated. It is our understanding that the sewers are being repaired.

Comparison of the ground-water table elevations for April and August indicates that the water-table surface maintains the configuration described above. Comparisons between water levels in individual wells indicate that water levels in wells around the periphery of the site (GW-21, GW-3, GW-8, GW-12) decreased between April and August while water levels in the area around the lagoons and the buildings to the north of the lagoons increased slightly (approximately 0.1 ft) over this same time period. Overall the greatest gradients (difference in water elevation) occurred in August. As noted earlier, August had little rainfall; as will be discussed later, our measured surface water flows were the lowest in August. Stream water levels also should have been the lowest. Conversely, April gradients were representative of the other five measurement events.

Lagoon Water Balance

One concern raised by Olin was whether or not the existing gypsum lagoons were leaking through the liners. Pirnie scientists used a water budget analysis to surmise that the Lagoon 1 (see site map) was leaking and to estimate the volume of water that leaked through the liner of the lagoon. Using precipitation measurements from the rain gauge on-site and the best possible estimates of the volume of water that could be evaporated from the lagoon surface, the expected water levels in the sludge were calculated. These expected water levels were then compared with measured water levels and the rate of discharge from the lagoon was calculated for two different values of sludge porosity (i.e., water stored in voids in the sludge). The total water loss from the lagoon was calculated by multiplying the difference in water levels by the total area of the lagoon. These calculations, summarized in Table IV-1, indicate that between 52,900 gallons and 240,000 gallons of water leaked through the boundaries of Lagoon 1 in approximately a one-month time span depending on the porosity value used. Similar volumes of water are speculated to be leaking from Lagoon 2, since it has received the same sludges and has been operated in the same fashion as Lagoon 1.

TABLE IV-1

CALCULATED WATER LEAKAGE FROM LAGOON 1

Time Span	Porosity	Water Lost (gallons)
March-April	30%	52,900
April-May	30%	218,000
March-April	50%	86,000
April-May	50%	240,000

Excavation of sludge and inspection of the lagoon liner in the fall of 1981 confirmed that the liner was perforated and allowed leakage of fluids from the lagoon. As will be described later, actions were initiated by Olin to replace the liners.

Overall Ground-Water Discharge

Calculations of ground-water flow velocities were based on hydraulic conductivities and gradients. The actual flow velocity through the glacial till, which, in most cases, constitutes a great portion of the saturated thickness of the aquifer, may be as low as 0.3 ft/day ($1x10^{-4}$ cm/sec). The average velocity is believed to be on the order of 0.5 ft/day ($1.7x10^{-4}$ cm/sec). Overall it is indicated that between 71,000 gpd (April data) and 88,000 gpd (August data) was discharged from the site. Both of these estimates include discharge of water from leaky lagoons (estimated at 8,000 to 10,000 gpd) and sewers and sumps (perhaps 2,000 to 4,000 gpd). Under natural conditions, actual ground-water discharge may be on the order of 59,000 gpd. The observed increase in ground-water discharge between April and August is probably produced by the increase in the hydraulic gradient which is observed on the site in August. Given the great variability in hydraulic conductivity of soils on the site (as much as two orders of magnitude) and errors in estimating the hydraulic gradients from water-table contours, ground-water discharge from the site is considered to be essentially constant.

Surface Water Flows

A surface-water monitoring system was established on the site to evaluate the response time of the surface water system to long-term and single-event variations in precipitation and to measure the total discharge from the site. The surface water is derived from runoff and ground-water discharge. The surface water monitoring program included installation of 13 stream gauging stations, including weirs and points where flow velocity measurements were taken. Surface-water sampling stations were chosen so that discharge at the upstream station could be subtracted from discharge at the downstream station to determine the approximate volume of surface water derived from the Olin site. The two weir locations were expected to yield more precise information than the other stations (see Figure IV-3 or Figure III-1 for the location of the measurement points). Table IV-2 summarizes the surface-water discharge measurements made during six sampling field trips to the Olin site.

TABLE IV-2

DISCHARGE RATES OF SURFACE WATER AT THE OLIN SITE
(million gallons per day)

	Mar.	Apr.	May	June	Aug.	Dec.
East Ditch SS-1	0.21	0.09	0.19	0.18	0.17	0.23
East Ditch SS-2	-	-	-	0.03	0.05	0.15
East Ditch SS-16	0.24	0.30	0.36	0.30	0.16	0.39
South Ditch SS-5**	0.18*	0.04	0.03	0.19	0.06	0.13
South Ditch SS-11**	-	-	-	-	-	0.10
South Ditch SS-N-A	-	-	-	-	-	0.30
South Ditch SS-N-F	-	-	-	-	-	0.27
South Ditch SS-12	-	0.10	0.13	0.01***	No Flow	0.05
"Net" Discharge****	0.21	0.25	0.20	0.31	0.05	0.29

* Flows measured prior to weir construction
** Weir
*** Before rain event
**** Sum of SS-16 minus SS-1 plus SS-5

As can be seen from the above table, surface water discharges from the site were highly variable. Net discharges can be calculated for the eastern 15 acre portion of the site (north of the South Ditch complex) contributing to the East Ditch by subtracting the flow at SS-1 from the flow at SS-16. The net increase ranged from about 210,000 gpd in April down to a calculated loss in August. It is believed that these August data represent a measurement error within the accuracy of the measuring device used. Since there was no evidence of recharge from the East Ditch into the site during August, a positive increase in flow almost certainly occurred in actuality.

The net discharge leaving through the South Ditch complex is more difficult to determine; as discussed earlier, some ground water is believed to leave the site to the west and reenter the site at SS-12. This station also receives contributions from the drainage area to the west of the Olin site. However, the net discharge from the South Ditch complex roughly ranges from a 180,000 gpd increase to a 100,000 gpd decrease; the decrease is attributed to storage in the South Ditch complex. This storage is represented by the intermittent pond mentioned previously.

The overall total net discharge through the East Ditch SS-16 and the South Ditch complex for the entire 57 acre site and the 43 acres to the west was as high as about 310,000 gpd. While the low value was measured to be 52,000 gpd, it is believed that a value of 60,000 gpd is probably more accurate. The above flows include cultural inputs.

Comparison of the average annual discharges from the site and the individual measurements collected during the six samplings illustrates how the hydrologic system responds to conditions of above and below normal precipitation. The minimum net discharges from the site were measured in August, the time indicated by the rain gauge to be the prolonged dry condition. Discharge through the South Ditch in August was 0.065 mgd, which is predominantly ground water and non-process cooling water; differences in discharge through the East Ditch are less than the detection limits of the flow meters used. Although June would be expected to be a normal precipitation discharge time period, the net site discharge was at a maximum, 0.32 mgd, and results from a measurement taken a day after a rain event of 1.5 inches in twenty-four hours. This discharge, which is predominantly surface water, illustrates that the maximum discharges from the site are related to discrete high intensity precipitation events. The December measurements were taken under prolonged high precipitation conditions in which both ground and surface water would respond to increased water supply. Therefore, the 0.29 mgd was representative of the maximum discharge that could be anticipated from the site over extended periods of time (weeks or a month).

Water Budget Calculations

Calculation of Typical Surface Water Discharges

Although the water system at the Olin site is too complex to permit water budget analysis of data collected at a single point in time, water budget calculations can be made using average annual data. The geologic, hydrologic, and geochemical information collected indicate that the ground water and surface water flowing from the site and the 47-acre drainage basin to the west discharges into the East Ditch and South Ditch complex and can be measured as discharge through SS-16 and SS-5.

Ground Water from the Olin Site - Water table contours show that the hydraulic gradients and saturated zone thickness remain fairly constant throughout the year. The total groundwater discharge through the site is approximately 71,000 gallons per day or 26 MG/year. This estimate includes man-made contributions: from the lagoons (about 8,000 to 10,000 gpd) and leaky sewers and sump (perhaps 2,000 to 4,000 gpd) so that the natural yield from the site would be on the order of 59,000 gpd or 0.50 MG/year acre.

Ground Water from Off-Site - The South Ditch also receives ground-water discharge from the drainage basin to the south and west of the Olin site. Approximately half (23 acres) of the off-site portion of the drainage basin is not believed to receive significant recharge from precipitation to produce ground water because of suspected low permeability of the soils and recent construction. Therefore, the remaining 24 acres of the drainage basin to the west based on the natural yield rates listed above would be expected to produce ground water at a rate of 0.50 MG/acre-year for a total of 12 MG/year of water from off-site ground-water discharge, based on experience elsewhere.

Runoff - In addition to the ground-water discharge discussed earlier, some of the precipitation which falls on the site leaves as surface runoff. Runoff rates for the general area around the site, as listed in existing literature, is estimated at approximately 12 inches per year for 37 inches of precipitation. At this rate the 100-acre drainage basin in which the Olin site is located produces 33 MG/year as surface runoff.

Total Typical Discharge - The calculations above indicate that approximately 71 MG/year of water is discharged from the site. It is inferred from geologic and hydrologic data in this study that all of this water discharges through the gauging stations at the furthest points downstream on the East Ditch (SS-16) and on the South Ditch (SS-5). For the six data sets the net discharge through these two points was calculated subtracting the discharge at SS-1 from the discharge at SS-16 and summing this with the discharge at SS-5. The net discharge calculated by this method ranged between 0.21 and 0.32 mgd with an average of 0.22 mgd (August data excluded because of anomalous data and non-correlation with average values). This typical flow of 0.22 mgd is approximately 81 MG per year and is in the same range as the calculated total discharge estimated from ground-water flow and runoff. The 81 MG per year typical measurement also includes man-made inputs to both surface and ground water. Table IV-3 summarizes the annual water budget calculations.

TABLE IV-3

ANNUAL WATER BUDGET SUMMARY

		Volume
1.	Estimated Component Contributions	
	Ground water from Olin site	26 MG/Y
	Off-site ground water from infiltration into the remaining 47 acres of the watershed	12 MG/Y
	Runoff from entire 100-acre drainage basin	33 MG/Y
	Total calculated yearly discharge, estimated:	71 MG/Y
2.	Total Typical Measured Discharge	81 MG/Y

Inorganic Material Analyses

A comprehensive program of ground-water and surface water sampling and analysis was conducted to identify materials present in the ground water at the site. Sample point networks and sample schedules were designed to identify the sources of materials, monitor material migration, and permit estimations of the quantities of various materials which discharge from the property.

Ground Water - Inorganic Chemistry. Samples of ground water were collected on six occasions and the concentrations of inorganic chemicals in these waters was measured. Appendix 3 summarizes the results of the inorganic ground-water chemical analyses. The concentration of each inorganic species was plotted on a site map and contoured to illustrate the distribution over the site. During the first sampling field trip all ground-water samples were analyzed for acidity, ammonia, chlorides, dissolved solids, nitrates, sulfates, volatile and base/neutral priority pollutants, and selected organic compounds. Sampling schedules were modified during the subsequent sampling periods based upon the results of the first sampling.

Approximate ambient or background values for chemical constituents in the ground water found in the glacial sediments of the Wilmington area, based on values listed in the USGS Water Supply Paper No. 1694 (1964) are shown in the following table.

Parameter	pH	Specific Conductance (umhos)	Temperature (°C)	Alkalinity (mg/l) as $CaCO_3$	Nitrogen (mg/l)	Chloride (mg/l)	Sulfate (mg/l)
Background Value	6.1	260	9.9	15	<1	4	11

o Specific Conductance. The contour map of specific conductance of ground waters collected from the site is shown in Figure IV-4. Specific conductance is a measure of the ability of a water sample to conduct an electrical current, a property which depends on the total concentration of chemical species dissolved in the water. Because the total concentration of dissolved species controls the specific conductance of water, Figure IV-4 can be interpreted as a map of the total dissolved material in the ground water. The area under Lagoons 1 and 2 immediately to the southwest has the highest concentrations of dissolved species (specific conductance greater than 10,000 umhos). Specific conductance of ground water generally decreases with distance from the lagoons although the areas near the West Ditch and the storage tanks on the northeast corner of the site also have high values.

Nested wells show that waters in the glacial till have greater concentrations of dissolved species than waters sampled from the sands. The specific conductances of the waters from each well fluctuated between sampling periods, but generally remained in the same order of magnitude. The general distribution of specific conductance shown in Figure IV-3 is observed through all sampling periods.

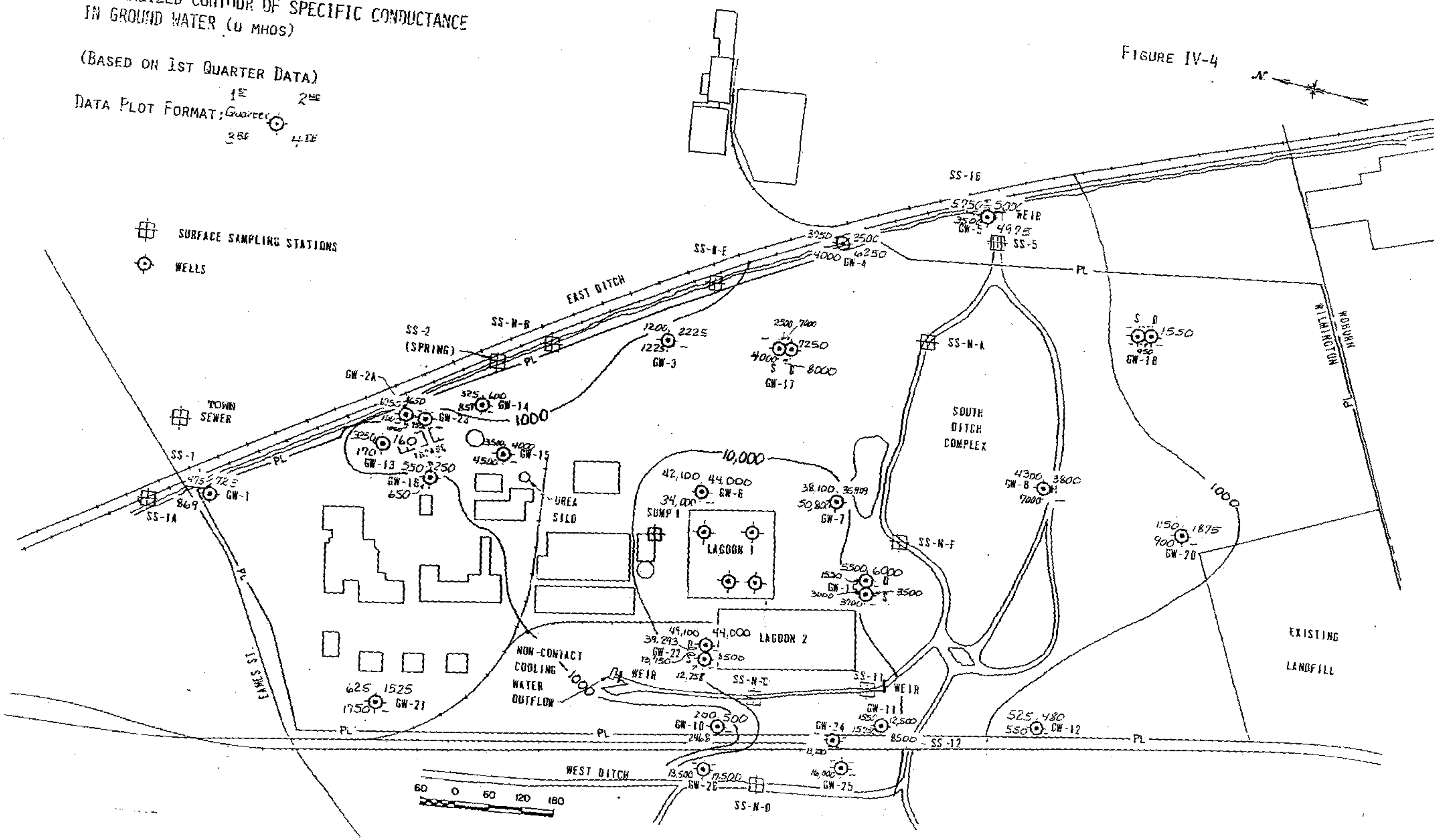
On the basis of the contours of specific conductance, there appear to be two source areas for dissolved species on

GENERALIZED CONTOUR OF SPECIFIC CONDUCTANCE IN GROUND WATER (u MHOS)

(BASED ON 1ST QUARTER DATA)

DATA PLOT FORMAT: 1st Quarter 2nd 3rd 4th

FIGURE IV-4



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the site, the sludge disposal lagoons and nearby sumps and the area surrounding the storage tanks. From these two source areas, materials seem to migrate with the ground water, predominantly to the south and southeast, but with a localized discharge from the southwest of Lagoon 2. There appears to be dispersion of the materials with migration, thus mitigating any possible impacts on surface water quality.

o <u>pH</u>. Ground water from wells directly to the east of Lagoon (GW-6, GW-7) and near the west boundary (GW-10) have low pH values. Wells in the extreme southern portion of the site (GW-18 and GW-20) have high pH values (9 to 11). The contour map of pH of ground waters collected from the site is in Appendix 6.

The pH of ground waters collected from beneath the storage tanks area varied from 4.5 to 6.9. The low pH values to the east of the lagoons, GW-6, are indicative of the presence of a source of H+ ions, such as an acid. Since the long abandoned acid neutralization pits were located in this area, remains of waste disposed there are a likely source of H^+. Low pH's in GW-10 also may be indicative of past on-site activities. The other area of low pH (GW-12) is located in the swampy area surrounding the southern stream where humic acids may be produced as a result of organic decay. The ground water sampled to the west of the lagoons (GW-11, GW-22S), have high pH values (8-10). The high pH values associated with part of the area around the lagoons may indicate contribution of basic anions from lagoon leakage. It is unclear why there are high pH values south of the South Ditch complex.

Relative pH values also tend to be consistent over the four sampling periods, but a general low in pH was observed in all wells in April and May. Comparison of pH values collected by GEI, Olin, EPA, and Pirnie shows that, except for a decrease in GW-6 and GW-8 and an increase in GW-11, the pH of ground water beneath the site has remained relatively constant.

Ground waters collected on-site were generally in the 5 to 7 range.

o Chloride and Sulfate. Chloride and sulfate behave in a similar manner to the specific conductance. These chemicals are found in high concentrations (Cl^- >1,000 mg/l, $SO_4^=$ >10,000 mg/l) near the lagoons and process buldings, in a pattern similar to the distribution of specific conductance. A contour map of chloride and sulfate concentrations in ground waters ampled from the site is in Appendix 6. The probable discharge directions, shown by the dashed lines, are the same as those for specific conductance, and concentrations are greater in the deep wells (versus the shallow wells). Comparison of samples collected previously by EPA, Olin and GEI and during the four sampling periods by Pirnie shows that concentrations of chemicals in the wells on the site generally remained constant over five years. Concentration of chloride decreased by an order of magnitude in wells GW-3 and GW-8 between the 1977-1978 sampling and the 1981 sampling. Conversely, the concentration of sulfate increased by an order of magnitude in GW-6 and GW-7 and by two orders of magnitude in GW-2 and 2A.

Also the concentrations of chlorides and sulfates were higher in the deeper wells than in the shallower wells of the nested well systems; this is not surprising considering our understanding of possible past activities. For instance, liquids with high specific gravities would tend to migrate downward.

The source areas for the chlorides and sulfates appears to be the lagoons, the northeast storage tanks and possibly material remaining from past acid pit disposal activities. It should be noted that there are no known activities related to the storage tanks which account for the presence of the chlorides and sulfates. However, a leaking sewer was replaced in that area during 1981.

o Alkalinity. Alkalinity is the ability of a solution to buffer (neutralize) acid. Since bicarbonate (HCO_3^-) is the dissolved species which buffers acid (i.e., reduces H^+ concentration) in the pH range of natural waters (4.5 to 8.3), alkalinity is usually expressed as concentration of $CaCO_3$. The contours show that the highest alkalinities (>1,000 mg/l) were observed in ground waters sampled to the west and south of the lagoons. Alkalinities greater than 100 mg/l are found in the area of the northeast storage tanks, as well as in the area around the sludge landfill. Waters from the other wells on the site generally have alkalinities less than 100 mg/l (within the range of natural waters). Alkalinity remained within the same order of magnitude in most of the wells over the entire 1981 sampling period. Alkalinity values in wells GW-6, GW-7, GW-10, and GW-12 varied by more than an order of magnitude, but always remained in the range of normal ground waters. Alkalinity was greater in deep wells than in shallow wells in all of the nested wells.

Sources of high alkalinity appear to be primarily the lagoons and, secondarily, perhaps the landfill or previous disposal activities for gypsum sludge. A contour map is in Appendix F.

o Ammonia. A contour of ammonia concentration, shown in Figure IV-5, shows that ammonia concentration, like most other dissolved species, is concentrated in the ground water around the lagoons (>1,000 mg/l) and decreases in concentration at greater distances from the lagoon. The wells around the storage tanks also have concentrations which may exceed 100 mg/l. The ammonia concentration in any given well usually remained within the same order of magnitude during the year, but higher concentrations of ammonia (varying by as much as an order of magnitude in wells GW-2 and GW-11) were observed in during May through August. As with the chlorides and sulfates, concentrations of ammonia in the deep wells exceed concentrations in the shallow wells of the nested well systems.

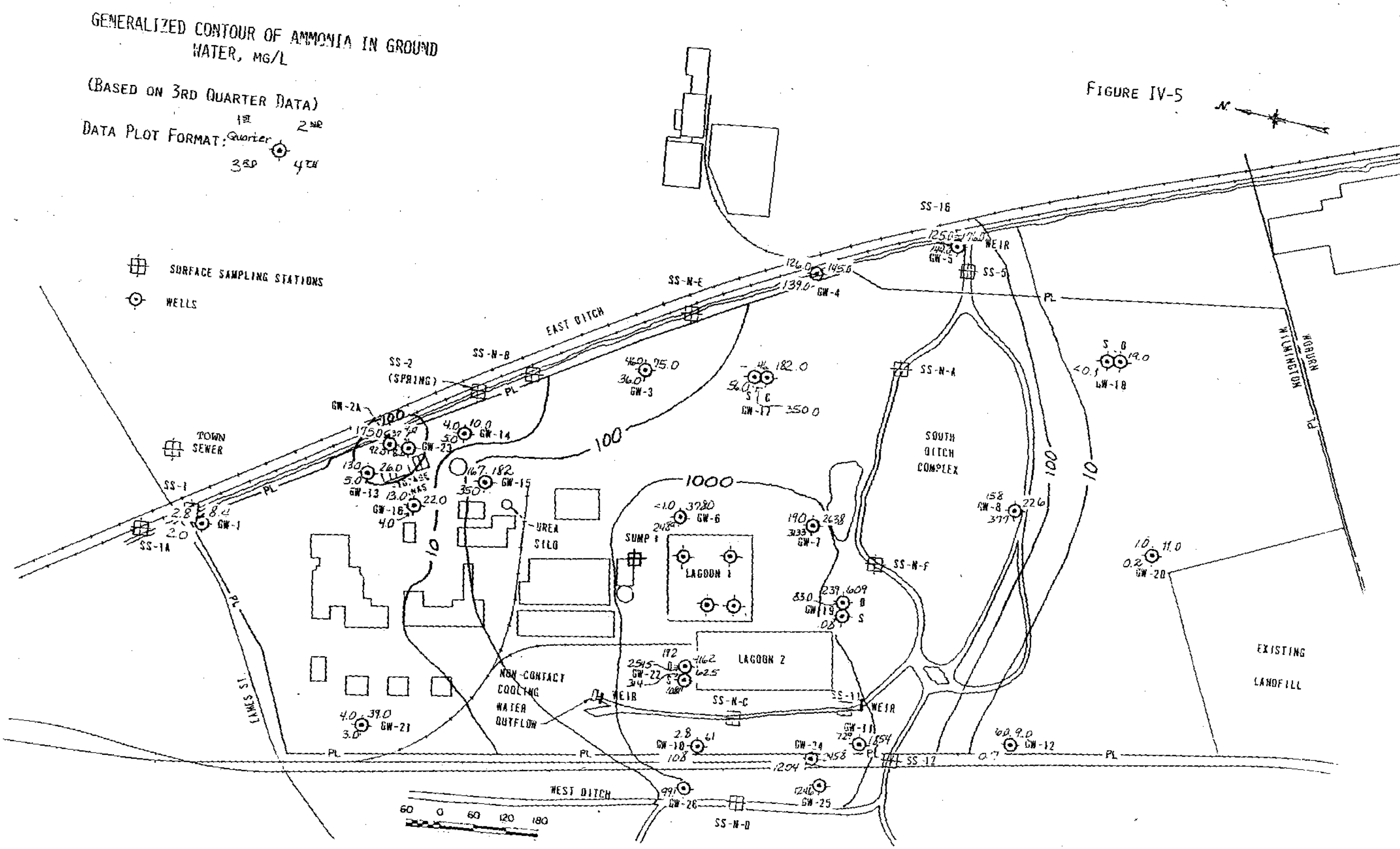

FIGURE IV-5

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The major source of ammonia is believed to be leakage from the lagoons and related facilities. A secondary source is the area around the storage tanks and may be related to the leaking sewer repaired earlier in 1981. Ammonia moves along the predominant routes of ground-water flow.

o Nitrates and Nitrites. Like the other chemical species, the highest concentrations of nitrates and nitrites (greater than 100 mg/l) are found near the lagoons with decreasing concentrations (1 to 10 mg/l) with increasing distance from the lagoons. The distribution shown is representative for a wet or dry season condition because nitrate and nitrite concentrations generally remained within an order of magnitude at any given well, except in GW-2 and GW-22D, where concentrations decreased by an order of magnitude and GW-22S where concentrations increased by an order of magnitude. Most wells showed an increase in these species in the dry season except GW-5 in which the concentrations decreased by two orders of magnitude. Nitrate and nitrite concentrations in the nested wells show no consistent patterns. Nitrate concentrations in 17D are greater than in 17S, less in 19D than 19S, and switch from a greater concentration in 22D to a greater concentration in 22S over the sampling period.

Measurements of dissolved oxygen in the wells on the site show that even in wells where ammonia concentrations are high, the dissolved oxygen concentrations are high. One would expect that nitrification would occur in ammonia bearing waters. Further, the ground water would be depleted in oxygen since nitrification is an oxygen consumptive reaction. However, it is possible that in areas with high ammonia concentrations are and/or low pH's that the nitrification reaction is erratic. However, it is believed that at least some of the nitrates and nitrites measured on the site are produced from nitrification. A contour map is in Appendix F.

o Chromium (+3 and +6). A contour map of chromium +3 is shown in Figure IV-6. Initially, high concentrations of total chromium were found in wells near the lagoons in acidified samples. Subsequent unacidified samples were analyzed for Cr^{+3} and Cr^{+6}. Chromium +3 generally occurred in concentrations at or below detection limits over the site, except in the area around the lagoons (GW-7, GW-22D) where it occurred in high concentrations (> 1 mg/l). The distribution shown is representative of chromium distributions throughout the year because concentrations have remained within the same order of magnitude during the entire sampling period with slight increases during the dry season. Nested wells 22D and 22S, the only nested wells with large enough concentrations to compare, indicate that chromium is more concentrated in the deeper glacial till sediments than in the shallow sands.

Chromium +6 occurred in low concentrations around the lagoons and was generally below detection limits over the rest of the site. The area around the landfill initially had moderate concentrations of Cr^{+6} (0.36 mg/l in GW-18D, 0.39 mg/l) which dropped to below detection limits by the last sampling period.

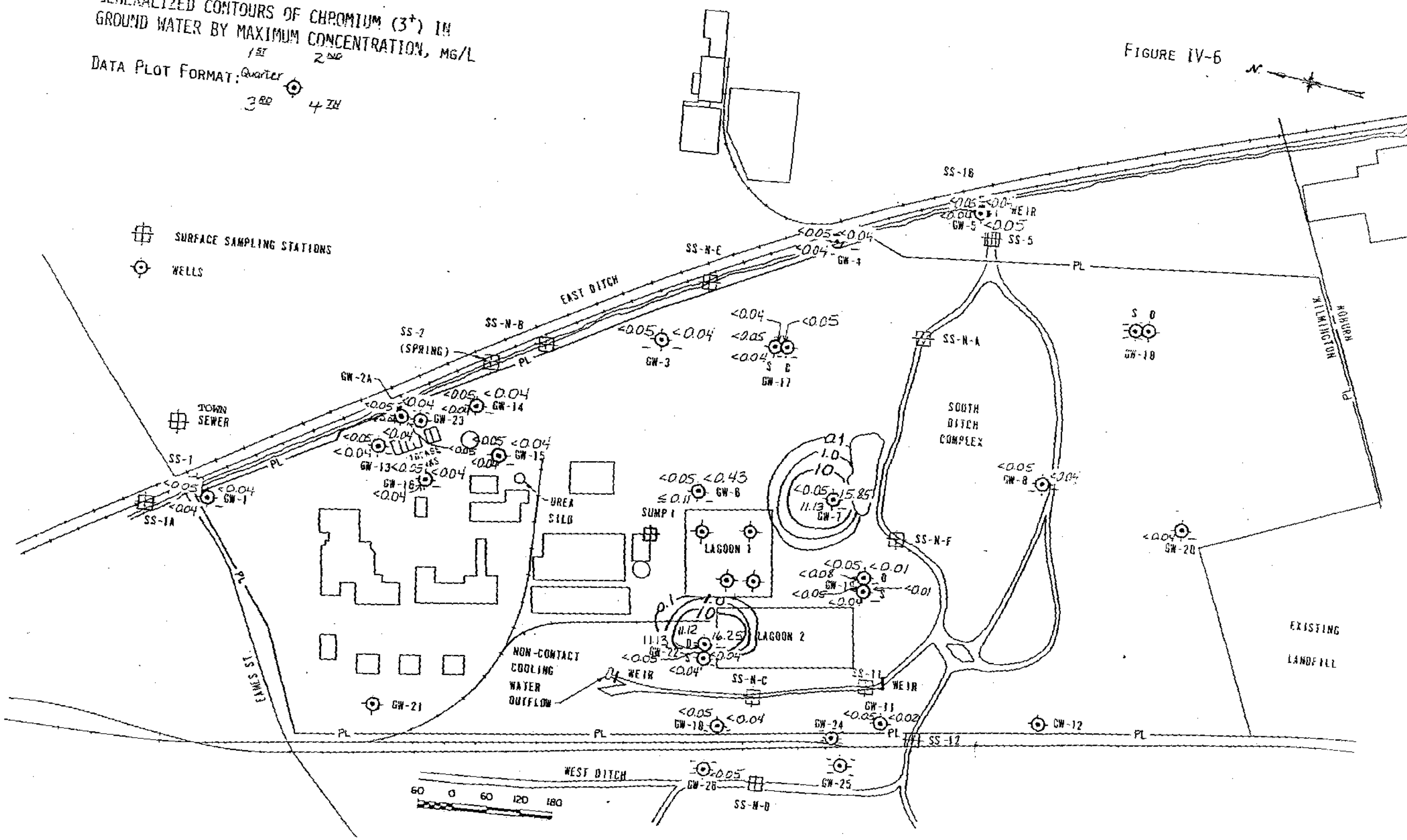
The source of chromium shown in Figure IV-6 is located around the lagoons. Chromium wastes were known to have been disposed in this general area. Since chromium +3 and +6 concentrations dropped to levels near or below detection limits by the end of the sampling period, especially at the site periphery, chromium should not be an element of concern.

o Cadmium and Lead. Water samples were also analyzed to determine concentrations of cadmium and lead. Elevated concentrations were found primarily in wells near the lagoons with some slightly elevated concentration in wells down gradient of the lagoons. In several cases, these concentrations decreased to low or below detection levels during the sampling period.

GENERALIZED CONTOURS OF CHROMIUM (3+) IN GROUND WATER BY MAXIMUM CONCENTRATION, MG/L

DATA PLOT FORMAT: 1ST 2ND Quarter 3RD 4TH

FIGURE IV-6



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The source of the cadmium and lead may be associated with the chromium source. Since the levels of these constituents decreased to near or below detectable limits over the sampling period, particularly at the site boundaries, these materials appear to be of no concern.

o <u>Temperature and Dissolved Oxygen</u>. Field measurements of temperature and dissolved oxygen content were made. Temperatures were within normal ranges of ambient values. Dissolved oxygen measurements indicate that the ground-water system exists under aerobic conditions. These parameters do not reveal any patterns which would indicate directions of ground-water flow or contaminant source and transport, such as a thermal gradient or indications of possible degradation due to anaerobic conditions.

Comparison of nested well data shows that the concentrations of inorganic constituents are greater in the glacial till than in the upper sand layer. This is not surprising since the ground-water flow is slower in the till; the present measurements may represent fluids which infiltrated the site at some previous time, but have not yet had adequate time to reach the site boundaries. Also, any fluids with a high specific gravity would have had a tendency to move more quickly downward through the sandy upper layer to the till.

<u>Surface Water - Inorganic Chemistry</u>

The concentrations of chemicals dissolved in surface waters flowing from the Olin site were measured to determine the mass of chemicals discharged from the site by surface water.

o <u>pH</u>. The pH of waters on the site generally range from moderately acidic (5.1) to slightly basic (7.4) with the average slightly acidic. These values are within the range of natural surface-water values. The spring in the East Ditch (SS-2), showed a basic pH value of 8.6. This indicates that the water in the spring has come in contact with materials related to man-made activities.

o Specific Conductance. Specific conductance of surface waters tested on the site ranged from 325 to 58,000 umhos. The lowest values were found at SS-1. SS-1 is upstream of points where chemicals discharge from the Olin site and is only somewhat above the ambient conditions which would be expected for this type of watershed. The relatively low values found at SS-11 reflect that non-contact cooling water was being sampled. Specific conductivity of surface waters tested at the downstream East Ditch sampling sites was generally greater than that at the related upstream site by several fold. Further, the values at SS-12 (end of West Ditch) and at SS-5 generally were even higher than at SS-16. Overall these values are indicative of contributions of materials from the site. The highest values of specific conductance (1,000 to 8,000 umhos) were observed down-gradient of the lagoons.

o Chlorides and Sulfates. Chlorides and sulfates both show distributions similar to the distribution of specific conductivity of surface water on the Olin site. The lowest chloride and sulfate concentrations were found in the station at the upstream boundary of the site (i.e., SS-1). While concentrations of these materials generally increased somewhat at the spring (SS-2) on the eastern boundary of the site. Based on ground-water data it appears that inputs of sulfates and chlorides occurred along the entire ditch; however, groundwater reach 2 (which is downstream of the reach containing the spring) appeared to contribute the most chlorides and sulfates. Of interest was that the pick-up of chlorides along the East Ditch has declined significantly over recent months; the pick-up of sulfates declined slightly.

High chloride sulfate values are present at SS-12 and SS-5. These values were most likely a result of influence from the lagoons or past activities on-site.

Of particular interest was the dramatic increase in the sulfate concentration to 4,220 mg/l at SS-5 right after a rain event in time. Data from other South Ditch sampling points indicate surface scour of sulfate deposits in the South Ditch area occurred.

Comparatively low concentrations of chloride (51 to 100 mg/l) and sulfate (30 to 66 mg/l) were observed in SS-11, due to the nature of the water being sampled and to possible dilution effects.

o <u>Nitrogen Species and Alkalinity</u>. The concentration distribution of ammonia and nitrate was nearly the same as specific conductivity. Low values were observed at the upstream boundary of the site at SS-1 (ammonia = <0.1 to 0.6 mg/l, nitrate = 0.9 to 2.1 mg/l and alkalinity = 41 to 366 mg/l). An increase in values was observed at the downstream monitoring location (SS-16). However, as with the chlorides, there is evidence of a decline over recent months along the East Ditch. While the spring at SS-2 appeared to have an ammonia input, based on ground-water data the ammonia appeared to enter along the entire East Ditch.

At both SS-5 and SS-12 earlier high values of ammonia and alkalinity also have declined recently. High concentrations of these materials were found in the lagoon liquid; hence the lagoons and related facilities are a source of the ammonia.

Low concentrations were again observed in SS-11 (ammonia = 2.8 to 17 mg/l, alkalinity = 28 to 800 mg/l), due to the nature of the non-contact cooling water. Nitrate nitrogen values were generally low throughout the study area except for the spring SS-2. Also some nitrate was measured in the lagoon liquid.

o <u>Chromium (+3 and +6)</u> - Concentrations of total chromium were initially found in the range from 0.010 to 0.42 mg/l, in acidified samples. However, in unacidified samples, chromium +3 and +6 to near or below the detection limits. By the end of the sampling session, concentrations of both species in all sampling stations had dropped below detection level (<0.05 mg/l for Cr^{+3}, <0.01 mg/l for Cr^{+6}).

o Cadmium and Lead - Surface water samples were analyzed for concentrations of dissolved lead and cadmium. Concentrations of these chemicals dropped below detection levels (0.04 mg/l for Pb and 0.01 mg/l for Cd) by the last sampling period.

Effects of the Existing Landfill

There is an existing landfill on the southwest corner of the site. This landfill was used by previous operators mainly for the disposal of calcium sulfate sludge. Because calcium sulfate is somewhat alkaline, high values of alkalinity, pH, and sulfate concentration in wells downgradient of the landfill would indicate contamination of ground water by chemical species leached from the landfill. Also the Woburn town sanitary landfill is located to the south of the site but may be in a different watershed. Sanitary landfills tend to have acidic leachates. Hence low values of pH and alkalinity would indicate an influence from the sanitary landfill. Since the Woburn landfill appears to be in a different watershed minimal influence was expected and none was found.

Sulfate concentrations are two orders of magnitude less (10-100 mg/l) in wells which would be affected by the existing landfill (GW-20, GW-18) than in the areas around the sulfate lagoons where sulfate concentrations are on the order of 1,000 to 35,000 mg/l. Sulfate concentrations in the wells which would be affected by the Olin landfill are only slightly higher than background levels. However, pH's of waters which could be influenced by the existing landfill (9.3 to 11.3) are three to five units above background level (6.1). The values are higher than would be expected for lagoon sludge (8.7 to 9.6).

The alkalinities of waters collected from wells that would be influenced by migration of materials from the existing Olin landfill are on the order of 160 to 350 mg/l, which is the same order of magnitude as concentrations in the wells around the lagoons. This is a moderate to high range of values compared with waters sampled from wells in other areas of the site and is an order of magnitude above the reported background surface water values of 15 mg/l.

pH and alkalinity levels which are elevated an order of magnitude or more above background levels indicate a possible movement of materials in ground water emanating from the existing Olin landfill. However, since the sulfate concentrations in the area down-gradient of the landfill are in the same order of magnitude as background levels, the effect of the Olin landfill on the ground water is considered to be minor.

Comparison of Ground-Water and Surface Water Chemistry

Comparison of ground-water and surface-water chemistry shows that materials of interest are distributed as would be expected for the hydrological system described above. Concentrations of inorganic materials are low in both the surface and ground waters upstream of the site. Concentration of materials dissolved in both ground and surface waters increases as water flows through the site. Plots of distribution of inorganic materials in ground water indicate that high concentrations (especially ammonia) are distributed under the entire area of lagoons, storage tanks and plant area. This ubiquitous distribution of materials suggests that sources other than the lagoons or storage tanks, such as the past practices and underground piping may continue to discharge chemicals into the ground water and then into the surface water. However, concentrations of materials dissolved in the ground water generally decrease with increasing distance from the source areas and concentrations in the surface waters are generally in the range of expected values if the ground waters are discharging and mixing into the surface water.

Inorganic Emission Rates

Comparison of the emission rates of materials in ground water into the surface water strongly supports the premise that materials traveling in the ground water are discharged to the three ditches which surround the site. Under dry conditions in August, emission rates were approximately 260 lbs/day chloride, 535 lbs/day of sulfate, and 185 lbs/day of ammonia, and were calculated to be discharged from the ground water into the ditches, as shown in Table IV-4. Under the same dry conditions, the net chemical load from all surface water discharged from the site was 350 lbs/day of chloride, 600 lbs/day of sulfate, and 350 lbs/day of ammonia. This seems to be a reasonably good balance.

During more typical conditions in April (several days after a rain event), ground-water discharges were approximately 480 lbs/day of chloride, 2,065 lbs/day of sulfate, and 185 lbs/day of ammonia, as shown in Table IV-5. At the same time the total net load emitted from the site as gauged at SS-16 and SS-5 was 535 lbs/day of chloride, 930 lbs/day of sulfate, and 350 lbs/day of ammonia. This also was a reasonably good balance. The sulfate loading in the ground water may be elevated because of flushing by water infiltrating from recent rain events. The sulfate loading in the surface was low because water was being ponded in the South Ditch complex. The ammonia emissions are comparable with values obtained by GEI in 1978.

Further, if Lagoon 2 is in the same condition as Lagoon 1, then comparable inputs of chloride, sulfate and ammonia into the ground water are possible. Rough calculations indicate that the two lagoons could leak about 125 to 500 lbs/day of chloride, 400 to 1,600 lbs/day of sulfate and 100 to 400 lbs/day of ammonia.

However on a day in June after a 1.5 inch rainfall, the net surface water discharge rates were 920 lbs/day of chloride,

TABLE IV-4

COMPARISON OF GROUND-WATER AND SURFACE WATER DISCHARGE RATES (AUGUST DATA)

GROUND WATER

Boundary	Reach	Discharge (gal/day)	$[Cl^-]$ (mg/l)	Cl^- Mass Discharge (lbs/day)	$[SO_4^=]$ (mg/l)	$SO_4^=$ Mass Discharge (lbs/day)	$[NH_3]$ (mg/l)	$[NH_3$ Mass$]$ Discharge (lbs/day)
East	1	31,000	95	25	80	21	9.2	2
	2	14,000	42	5	362	42	36	4
	3	7,600	465	29	1,150	73	179	11
	4	9,500	25	2	73	06	BDL	-
Subtotal		62,100		61		142		17
South	3	7,480	1,600	100	2,300	143	1,204	75
	5	3,740	2,200	69	5,680	176	2,458	77
	6	748	250	2	590	4	108	1
Subtotal		11,970		171		323		153
West	5	-0-		-		-		-
	6	13,942	250	29	590	69	108	13
	7	710	110	0.1	11	0	2.6	0
Subtotal		14,013		29		69		13
Total		88,100		261 lbs/day		534 lbs/day		183 lbs/day

SURFACE WATER

Approximate Net Discharge		77,500		350 lbs/day		600 lbs/day		350 lbs/day

TABLE IV-5

COMPARISON OF GROUND-WATER AND SURFACE WATER CHEMICAL DISCHARGE RATES (APRIL DATA)

GROUND WATER

Boundary	Reach	Discharge (gal/day)	[Cl^-] (mg/l)	Cl^- Mass Discharge (lbs/day)	[$SO_4^=$] (mg/l)	$SO_4^=$ Mass Discharge (lbs/day)	[NH_3] (mg/l)	[NH_3 Mass] Discharge (lbs/day)
East	1	11,000	2,150	197	35	3.2	6.3	0.57
	2	24,000	66	13	831	166	27	5.4
	3	7,300	474	29	2,325	141	137	8.3
	4	8,200	163	11	1,030	70	12	0.82
Subtotal		50,500		250		380		15
South	3	14,960	1,083	135	10,635	1,325	635	80
	5	1,220*	2,040	21	7,900	80	2,002	20
	6	464	2,040	8	7,900	30	2,002	8
Subtotal		16,644		164		1,435		108
West	5	-0-						
	6	3,800	2,040	65	7,900	250	2,002	63
	7	19	112	0.02	6	<0.01	7.3	<0.01
Subtotal		3,819		65		250		63
Total		71,000		480 lbs/day		2,065 lbs/day		185 lbs/day

SURFACE WATER

Net Discharge	252,000	535 lbs/day	930 lbs/day	230 lbs/day

7,200 lbs/day of sulfate and 900 lbs/day of ammonia. The increase in total net loading from the site is believed to have been caused primarily by a great increase in the surface water discharge related to the high-intensity precipitation event. The marked increase in concentration of some materials (especially sulfate) under wet conditions may be due to scouring of materials from the ground as surface water flows over the site.

Conversely, the net load emitted in the surface water in December, a period of sustained wet conditions in which high loading rates would be expected, decreased to approximately 110 pounds per day of chloride, 425 pounds per day of sulfate, and 81 pounds per day of ammonia. The chloride and ammonia emissions were significantly lower, while sulfates were only somewhat lower. As will be discussed later, while it is believed that remedial measures enacted to date may have contributed to this reduction in part, additional data are needed before this reduction can be classified as more than part of a downward trend.

Organic Material Analyses

Ground-water and surface water samples were analyzed for volatile and base/neutral (B/N) priority pollutants. On several samples non-priority pollutant volatile and B/N materials were identified. For convenience in this report, organic data were grouped into three ranges: a lower range - above detection limits but less than 0.05 mg/l, medium range - 0.05 to 0.20 mg/l; and an upper range - concentrations greater than 0.20 mg/l. The discussion of the data in terms of ranges seems appropriate given the known analytical variability.

Ground-Water Volatiles

Volatiles. Olin ground-water samples were analyzed for 31 volatiles listed on the Priority Pollutant list. The thirteen volatiles listed below were detected at least once at the Olin site. The data are in Appendix E.

1. Benzene
2. Bromoform
3. Carbon Tetrachloride
4. Chlorodibromomethane
5. Chloroform
6. Dichlorobromomethane
7. 1,2 Dichloroethane
8. Ethylbenzene
9. Methyl Chloride
10. Methylene Chloride
11. 1,1,2,2 Tetrachloroethane
12. Toluene
13. 1,1,1 Trichloroethane

Of the compounds listed above, volatiles with elevated concentrations in the ground-water regime are bromoform, 1,2 dichloroethane, toluene, and methylene chloride. Methylene chloride concentrations fluctuated widely over the sampling period and over the site. Methylene chloride was found in upper range concentrations (GW-4, GW-5, SS-5, SS-12) during the last sampling round, but there appeared to be no correlation with other compounds. Although the possibility cannot be discounted that minor amounts of this compound were used on-site in the past, it is more likely that the erratic methylene chloride results are related to analytical problems commonly associated with the use of this compound in certain laboratory procedures; therefore, it will not be discussed further in this report.

There appear to be two minor areas of volatiles in the ground water. The first area is around the northeast storage tanks, where mid to upper range concentrations of toluene were found in wells GW-2+2A and GW-16.

The second area of high concentration is around the lagoons and the nearby plant area. Moderate to high concentrations of bromoform, 1,2 dichloroethane and toluene appear in wells GW-6, GW-7 and GW-19D which surround the lagoon area. As discussed earlier, Lagoon 1 (and probably Lagoon 2) is believed to have had a ruptured liner during this study. This condition would have allowed infiltration of liquid into the ground water. Analysis of the Lagoon 1 liquid showed it to have lower range concentrations of 1,2 dichloroethane and toluene.

The vertical location of the volatiles in the subsurface does not appear to be controlled by the geology. A comparison of the nested well data obtained from the shallow and the deep wells indicates that there appears to be no correlation between the depth of a well and its volatile concentration. This is to be expected since volatilization of these compound may act as a significant removal mechanism before the compounds reach the ground water.

The most significant factor governing the location of volatiles is proximity to the source of contamination. It appears that volatile concentrations drop off significantly a fairly short distance away from the areas of concentrations above 0.2 mg/l. Although there may be minor areas of upper range volatile concentrations on-site, by the time the ground water discharges into the surface water, volatile concentrations consistently have dropped to near or below detectable limits. Thus, there appears to be little or no input of volatiles from the ground water at the Olin site into the surface water.

The variation in volatile concentrations between wet and dry conditions also shows no pattern. Since most of the variations were within an order of magnitude, the variations seen may be due to natural fluctuations in the ground water.

Surface Water - Volatiles

Of the twelve volatiles detected in the ground water (excluding methylene chloride) only five were detected in the surface waters. One volatile was detected once in the surface water but not in the ground water. The data are in Appendix 5. Of significance is that volatiles were only measured in the East Ditch and with the exception of one trichloroethylene sample, the highest concentrations were entering the site at station SS-1 on the northern boundary. Supplemental sampling to the north of the site in the East Ditch (SS-1A) confirmed that lower range concentrations of chloroethane and 1,1,1 trichloroethane and high concentrations of toluene were originating from off-site.

By the time station SS-16 was reached, the chloroethane and 1,1 dichloroethane were below detection limits. Also the toluene and 1,1,1 trichloroethane concentrations were reduced significantly by the time SS-16 was reached. For instance, in December the toluene concentration dropped from 0.31 mg/l at SS-1 to 0.043 mg/l at SS-16, while the flow only increased 70 percent across the site. Further, the concentrations of toluene and 1,1,1 trichloroethane decreased over the course of the study at both SS-1 and SS-16.

In regard to trichloroethylene, it was only measured above detection limits in one sample at SS-16. The source of the 0.053 mg/l measured in that sample is unclear. It is possible that it is related to off-site man-made activities to the east of the Olin site; a drainage pipe does enter the East Ditch from the east just a few feet downstream of SS-16.

Overall, the Olin site is not believed to be the source of any volatile organic compounds in the surface water. Hence no discharge rates were calculated.

<u>Ground Water - Base/Neutrals</u>

Olin ground-water samples were analyzed for forty-one base/neutral (B/N) compounds by CompuChem. The eleven listed below were detected at least once at the site. The data are in Appendix E.

1. Acenapthalene
2. Anthracene
3. Bis (2 ethylhexyl) Phthalate (DOP)
4. 4-Bromophenylphenyl ether
5. Butyl Benzyl Phthalate
6. Di-N-Butyl Phthalate
7. Fluorene
8. Napthalene
9. N-Nitrosodiphenylamine
10. Phenanthrene
11. Dioctyldiphenylamine

Only six of the above compounds were found in elevated concentrations in the ground water: bis (2 ethylhexyl) phthalate (DOP), butyl benzyl phthalate, di-n-butyl phthalate, "N-nitrosodiphenylamine" and dioctyldiphenylamine. N-nitrosodiphenylamine was actually detected as diphenylamine by CompuChem; the diphenylamine also included N-nitrosodiphenylamine. Further analysis showed that the "N-nitrosodiphenylamine" values listed in Appendix 5 are only approximately 20% N-nitrosodiphenylamine, based on analysis of one sample.

There appear to be two source areas of B/Ns on-site. The first is around the northeast storage tanks as shown by mid to upper range concentrations of B/Ns in wells GW-2+2A, GW-13, GW-14, GW-15, GW-16, and GW-23. This source appears to be very localized and is probably due to past activities in the area around the tanks. The second area appears to be around the lagoons. This source area is much more generalized, and is evidenced by mid to upper range concentrations, primarily in well GW-22S. The lagoons may also be a source of base/ neutrals, since analysis of the lagoon liquid showed it to have high concentrations of DOP and low concentrations of dioctylphenylamine.

DOP occurs in upper range concentrations in both areas, with the highest concentrations occuring near the storage tanks. DOP is present over most of the site. It was detected in 20 out of 25 wells analyzed for DOP. A generalized contour map is shown in Figure IV-7.

N-Nitrosodiphenylamine and dioctyldiphenylamine are distributed around the source areas in a similar fashion to DOP, but they are less widespread over the site. Butyl benzyl phthalate and di-n-butyl phthalate occurred in low to moderate concentrations around the two source areas.

A comparison of concentrations over the course of this study indicates that there is no clear-cut change in B/N

GENERALIZED CONTOUR OF BIS (2-ETHYL HEXYL) PHTHALATE IN GROUND WATER, MG/L

(BASED ON 1ST QUARTER DATA)

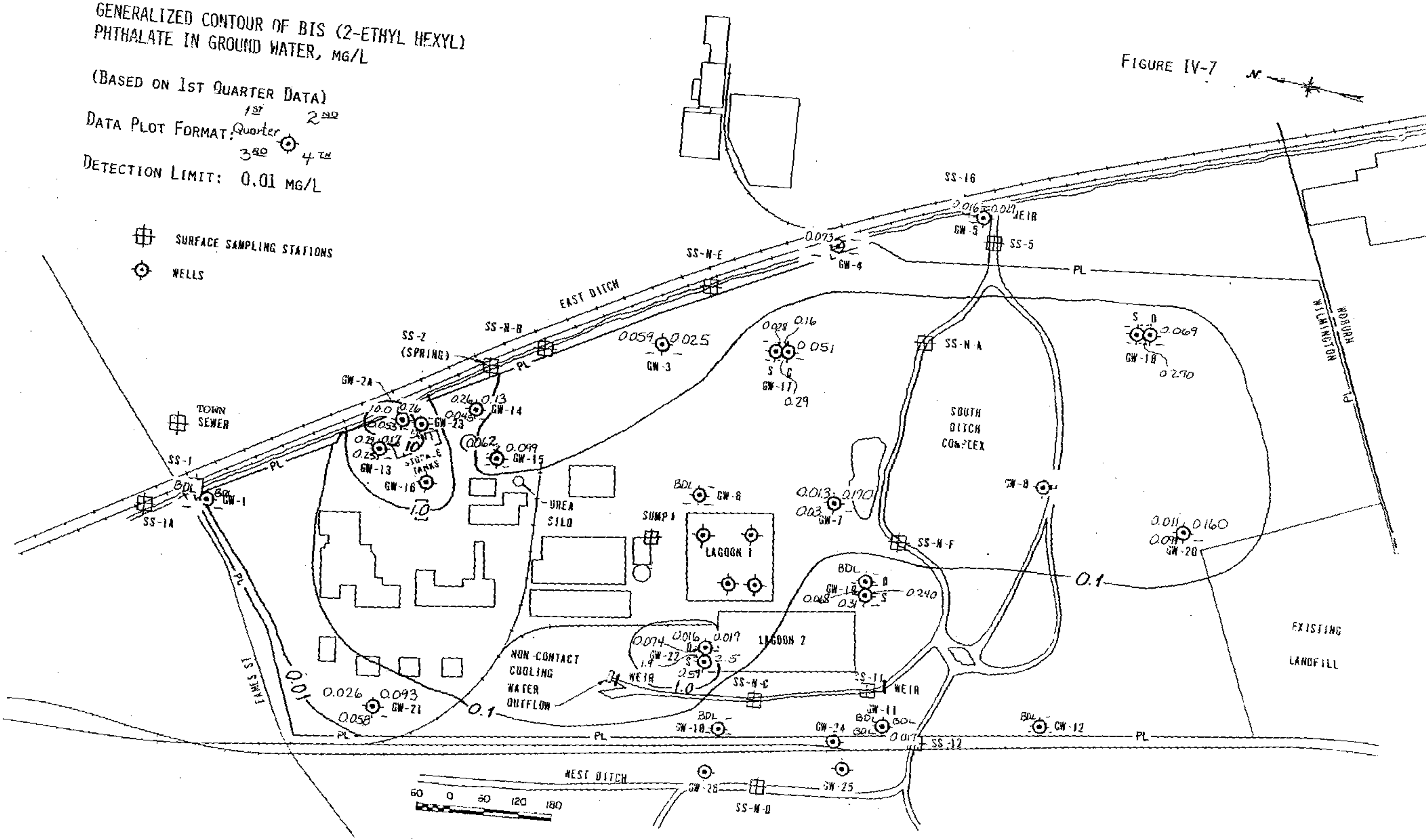
DATA PLOT FORMAT: 1ST Quarter 2ND 3RD 4TH

DETECTION LIMIT: 0.01 MG/L

SURFACE SAMPLING STATIONS

WELLS

FIGURE IV-7



concentrations over time. However, certain materials such as di-n-butyl phthalate, and butyl benzyl phthalate have decreased in concentration during the study.

<u>Vertical Distribution of Base/Neutrals</u> - There appears to be some correlation between the type of subsurface material and concentrations of base-neutrals, in particular, DOP. Wells whose screens are set in the till generally seem to have higher concentrations than the wells with screens set in the sandy outwash material. The nested well data show mixed results. GW-17S and GW-17D indicate that DOP is traveling in the deeper layers. GW-19S and 19D show the opposite; but since this area is a discharge zone, those results are not anomalous. GW-22S and 22D also show B/N movement primarily in the shallow zone.

The DOP concentrations generally seen in the deeper layers may possibly be a residual from past activities. In addition, the till generally has greater CEC values than does the outwash material, indicative of a greater capacity to adsorb contaminants. The sites for adsorption initially were filled during recharge by highly contaminated water in the past; less highly contaminated water now flowing through the till may be leaching contaminants from the adsorption sites. However, investigation of the area around the northeast storage tanks during the test pit work showed that the black liquid containing the majority of the base/neutral compounds primarily was contained in the unsaturated zone and at the surface of the ground water. The apparent immiscibility of the base/neutral compounds is supported somewhat by their relatively low solubilities. Overall, the mechanisms resulting in the vertical distribution of DOP (and to a lesser extent N-nitrosodiphenylamine) on the site are complicated.

<u>Surface Water - Base/Neutrals</u>

The base/neutrals that have been detected in the surface water are DOP, N-nitrosodiphenylamine, and, in one sample, dioctyldiphenylamine. Monitoring of the surface water at the Olin site indicates that discharge of B/Ns into the surface water occurs primarily on the eastern side of the site. B/Ns do not appear to be coming in from off-site to the north as was the case with the volatiles. SS-16, which monitors the East Ditch above the confluence, contained the highest concentrations of B/Ns: mid to upper range amounts of DOP, sometimes moderate amounts of N-nitrosodiphenylamine, and sometimes lower range amounts of dioctyldiphenylamine. Sources of the high concentrations of DOP and N-nitrosodiphenylamine in the East Ditch, shown by SS-16, are probably both leakage from the banks near the northeast storage tanks and from ground-water contribution. The spring in the East Ditch (SS-2) contributes lower range concentrations of DOP. SS-12, which monitors flow from the West Ditch and the area to the west of the site, contained no B/Ns at detectable levels, while the process-water outflow (SS-11) contained very low concentrations of DOP, just at the detection limit. South Ditch complex inflow (SS-5) to the East Ditch contained low to moderate amounts of DOP which decreased to below detectable limits in the last sampling period.

Variations Over Time - The DOP and dioctyldiphenylamine in the surface water have decreased somewhat over time. In the last sampling period, SS-16 was the only sampling station that showed any base/neutrals above the detection limit. However, it is possible that SS-5 may continue to contain DOP on an intermittent basis in the near future. At SS-16 DOP and N-nitrosodiphenylamine typically appeared in moderate concentrations. However, a high concentration of DOP occurred in May while N-nitrosodiphenylamine was below detection limits in August.

Emissions - While most of the DOP and N-nitrosodiphenylamine at SS-16 appears to be from the ground water, balances of emissions with surface water discharge were complicated by the use of absorbent booms in the East Ditch for organic recovery. Roughly 0.1 to 2.5 lbs/day of DOP were calculated to be emitted from the ground water, while 0.15 to 5.0 lbs/day were measured leaving the site. A typical value appeared to have been 0.4 lbs/day. In regard to N-nitrosodiphenylamine a typical value leaving the site during the study appears to have been 0.1 lbs/day (as N-nitrosodiphenylamine).

Other Organic Analyses

Non-priority pollutant volatile and base/neutral analyses were performed on samples taken during the 2nd quarter from one ground-water sampling station, GW-5, and three surface water stations, SS-2, SS-5 and SS-16. The analyses were performed in order to delineate other organics present at the Olin site. The data are in Appendix E.

There were no non-priority pollutant base/neutrals above detection limits in GW-5. The only volatile that was detected was acetone, at mid-range concentrations (0.05-0.2 mg/l).

Relative to the surface samples, the spring (SS-2) showed three base-neutral compounds at lower range concentrations (<0.05 mg/l). SS-5 contained no base/neutral compounds above detection limits and had one volatile, acetone, at upper range concentrations (>0.2 mg/l). SS-16 had four base/neutral concentrations at lower range concentrations and ten volatile compounds at lower to mid-range concentrations.

Comparing these results with previous analysis of non-priority pollutants performed by Olin shows that only one volatile compound was found in both samplings: 2, 4, 4 - Trimethyl-1-pentene. No base-neutrals were repeated in both periods. The source of the above materials is unknown.

V. RECOMMENDED PLAN FOR REMEDIAL MEASURES

Materials of Possible Concern

As discussed in the previous chapter, the Olin site is discharging variable quantities of three inorganic materials (ammonia, chlorides and sulfates) and low quantities of two organic priority pollutants (DOP and N-nitrosodiphenylamine). All other inorganic and organic materials studied appear to be of no concern.

The net ammonia discharge from the site was the lowest in the most recent sampling period in December 1981. It was measured at 81 lbs/day versus 350 lbs/day typically measured earlier in the study. This is considered to be part of a downward trend; without remedial actions sustained discharges below 100 lbs/day are not expected. Since the ammonia can contribute to water quality problems downstream of the site, this downward trend is encouraging. Additional actions appear warranted to assure that the trend continues. Lagoon 1 has already been renovated.

Similar to the ammonia, chloride discharges also were measured at their lowest levels in December. Net chloride discharges were 110 lbs/day versus more typical discharges of 350 to 535 lbs/day. While it is expected that this trend will continue as a result of remedial measures for other materials, it does not appear that even the typical chloride discharge represents a significant water quality problem.

While sulfate levels also dropped in December, the decline was not as much as with the ammonia or chlorides. While it is expected that this trend will continue as a result of remedial measures for other materials, even at typical values of 600 to 930 lbs/day, it does not appear that even the typical net sulfate discharges represent a significant water quality problem.

Insofar as priority pollutant organics are concerned, both DOP and N-nitrosodiphenylamine appear to be discharged at a typical rate of 0.4 lbs/day and 0.1 lbs/day for DOP and N-Nitrosodiphenylamine, respectively. Some additional action may be warranted. Appropriate remedial measures will be discussed below.

Sources of Materials Being Discharged

During the course of this evaluation two major source areas of materials being discharged were clearly identified: the lagoon area and related facilities; and the northeast storage tank area including the spring. A third "area" suspected to contribute is the underground piping.

The lagoons are believed to be leaking and contributing a significant portion of the ammonia, chloride and sulfate discharged from the site. Further, it appears that gypsum sludge has been generally deposited to the south of the lagoons from past practices and it is believed that scouring of this sludge may contribute to the high concentrations of sulfate in the surface waters.

The spring (SS-2) near the northeast storage tank area also is a secondary source of ammonia, chlorides and sulfates. The cause for this spring is unclear, but is suspected to be related to a piping leak of some type.

The major source of priority pollutant organics leaving the site is the northeast storage tank area. Test pit work in that area confirmed the general presence of organics believed to be related to the materials oozing through the bank of the East Ditch. Remedial actions have been implemented in this area.

During the course of this investigation it was determined that the effluent sewer discharging to the local sewerage system was leaking in the vicinity of the northeast storage tanks. This leakage is believed to have contributed mainly ammonia, chloride and sulfate to the ground water in that area. This corroded sewer was replaced during the investigation as a remedial measure. However, it is possible that others may also be leaking. Further, the influent sump to the treatment works was found to be leaking. This was also repaired during this study.

Remedial Measures

Any solution to a water contamination problem is complex. If no imminent hazard is present, then a phased approach is usually the most logical. Since no imminent hazard exists at the Olin site, a phased approach will be discussed. Of the inorganic and organic materials of possible concern discussed above, ammonia is considered to be of somewhat greater concern than the organics. The first phase of any remedial measures program should address reductions of ammonia. Chlorides and sulfates also are of some interest and are expected to be related to reductions in ammonia. The second phase of the program should address reductions in priority pollutant organics. The third phase would include monitoring to quantify the improvements obtained by earlier phases.

Phase I - Ammonia and Other Inorganics

The lagoons are the primary area for application of remedial measures for ammonia. As discussed earlier, the lagoons are believed to be the largest single source of ammonia. They also are a major source of sulfate and chloride, and a minor source of organics. The primary remedial measure in the lagoon area is excavation of sludge and replacing the liners with a more secure liner system. This action was completed for Lagoon 1 in December after the last sampling field trip. As a part of the lagoon liner replacement, ground water was pumped to dewater the lagoon for about two months. Improvements in water quality which have been observed recently may in part be a result of this dewatering action. Removing the sludge and replacing the liner in Lagoon 2 should further reduce the concentrations of ammmonia, sulfate, and chloride in the area around the lagoons and eventually in the surface waters. It is our understanding that Olin has scheduled repair of Lagoon 2 for this year (1982).

The new lagoon liner system consists of 12 inches of sand overlain by a 36 mil reinforced hypalon liner overlain by 12 inches of sand, filter fabric and 12 inches of gravel. This system represents a dramatic improvement in the ability to prevent future breaches in the liner. During the summer shutdown in 1981 a thorough inspection of the influent sump and on-site treatment facilities was made by Olin. The repairs discussed earlier are expected to reduce losses of inorganics.

A third action already completed was the replacement of the effluent sewer discussed earlier. This leakage not only discharged inorganics to the ground water near the East Ditch, but also probably increased the seepage rate through the bank of the ditch. It was recommended that an investigation of all underground piping be initiated to determine whether any other pipes are leaking. It is our understanding that a sewer inspection program has been implemented. Also, it is hoped that a point of origin for the spring (SS-2) could be found. Investigations to date have failed to locate anything which would serve as a source of head to drive water (and associated materials) upward into the East Ditch.

Another action worth considering is the relocation of the non-contact cooling water discharge to the East Ditch. This relocation might reduce hydraulic heads slightly on the western side of the site and also would reduce flows through the South Ditch complex.

Phase II - Organics

Discharge of both organic and inorganic chemicals from the site, especially into the East Ditch, can be decreased by remedial measures in the storage tank area. Initially, many different approaches were considered in order to reduce contamination associated with the storage tanks. However, supplemental test pit investigations help to narrow the list of possible actions by indicating that: 1) contaminated soil is more widely spread toward the plant than assumed in initial remedial calculations, 2) the area under the tanks is essentially lined by an impervious spilled resinous material, 3) the majority of the contamination is concentrated just above the water table and in the capillary zone (8 to 10 feet below grade). Hence, installation of an impermeable cap around and under the tanks was excluded because the area under the tanks is essentially lined by impervious spilled resinous material. Second, minimum (shallow) excavations around and under the tanks was eliminated because the zone of high concentration of organics in the soil was found too extensive to be removed by minimum excavation.

Measures considered included recovery wells, interception ditch, slurry wall around the area, detergent application and microbial degradation. Of these measures, detergent application, recovery, and disposal was eliminated because this would require extensive and costly feasibility studies both before and during the treatment process. Even in a well conducted cleanup, detergents may be difficult to control and may cause legal problems. Microbiological degradation was also rejected. Like detergent application, recovery, and disposal, microbiological degradation is a difficult process to control; it may also create unknown by-products and may be very costly. Of the three remaining techniques, a multiple recovery well system or an interception ditch with a recovery pump are fairly equivalent in effectiveness. Both approaches represent a positive action, but potentially a long-term commitment to remove materials from the ground water. While some organics may pass by either system, over the long term the discharge of organics will abate. It is anticipated that the recovered water would be discharged to the public sewerage system after decanting any organic layer generated.

Alternatively, the slurry wall approach represents an effort to contain the organics in place. This passive approach results in near-term discharge reductions, but retains the undesired potential for organic discharge at some time in the future. It is also more costly than a recovery well system or interception ditch. Considering the nature of the organics being discharged and all other factors, serious consideration was given to implementation of either a multiple recovery well system or an interception ditch. It is our understanding that Olin has implemented a multiple well recovery system.

Because contaminants which have accumulated in and on the banks of the East ditch represent a substantial source of contaminants which may be readily transported off the site by stream flow, removal of this material is deemed an essential remedial measure. During excavation, a series of sorbent booms and pillows should be installed downstream along the drainage ditch. Heavily contaminated sediment excavated from the channel (estimated at about 5 cubic yards, 20 drums) should be drummed and sent off-site. The remainder of the excavated material should be spoiled in front of the storage tanks. The excavated area should be filled with a clean coarse granular material.

The remedial measures described above should decrease the concentration of materials in the zone of organic ooze along the railroad on the eastern embankment.

<u>Phase III - Monitoring</u>

The measures proposed above should reduce the discharge of materials from the Olin site. However, further monitoring of the ground and surface water should be done to document the efficiency of the remedial measures implemented and to determine if any further action appears warranted.

The following schedule shows the suggested ground-water and surface water monitoring program for 1982 and 1983. The program should be implemented about 3 months after the removal of the sludge of Lagoon 2. The following tasks should be performed; all of these tasks would be subject to modification in scope based on previous results.

1. <u>Ground-Water Levels</u>: Water levels should be taken in all wells to monitor the ground-water flow and to observe any decreases in mounding around the lagoons.

2. <u>Surface Water Flows</u>: Surface water flows should be measured in the surface sampling stations listed in the schedule.

3. <u>Chemical Analyses</u>: The chemical analyses performed during each period should consist of the following parameters. The sampling stations and specific analyses to be performed for each period are listed in the schedule.

Inorganics:	Chloride (Cl)
	Sulfate (SO_4)
	Ammonia (NH_3)
	Specific conductance (S.C.)
	pH
	Chromium +3 (Cr^{+3})
Organics:	DOP
	N-nitrosodiphenylamine (N-N)

<u>Monitoring Schedules</u> - Two sampling periods, approximately 6 months apart, are recommended for 1982. Table V-1 shows the list of activities. Table V-2 shows the list of activities for the one recommended sampling period in 1983.

TABLE V-1

1982 MONITORING SCHEDULE

	Ground-Water Levels	Inorganics						Organics	
		Cl	SO_4	NH_3	S.C.	pH	Cr^{+3}	DOP	N-N
GW-1	*	*	*	*	*	*			
GW-2A	*	*	*	*	*	*		*	*
GW-3	*								
GW-4	*	*	*	*	*	*			
GW-5	*								
GW-6	*	*	*	*	*	*			
GW-7	*	*	*	*	*	*	*		
GW-8	*	*	*	*	*	*			
GW-10	*	*	*	*	*	*			
GW-11	*	*	*	*	*	*	*		
GW-12	*								
GW-13	*	*	*	*	*	*	*		
GW-14	*								
GW-15	*	*	*	*	*	*	*		
GW-16	*								
GW-17S	*								
GW-17D	*	*	*	*	*	*			
GW-18S	*								
GW-18D	*								
GW-19S	*	*	*	*	*	*			
GW-19D	*	*	*	*	*	*			
GW-20	*								
GW-21	*								
GW-22S	*	*	*	*	*	*			
GW-22D	*	*	*	*	*	*	*		
GW-23	*								
GW-24	*	*	*	*	*	*			
GW-25	*	*	*	*	*	*			
GW-26	*	*	*	*	*	*			

SURFACE WATER

	Flow Measurements	Inorganics						Organics	
		Cl	SO_4	NH_3	S.C.	pH	Cr^{+3}	DOP	N-N
SS-1	*	*	*	*	*	*		*	*
SS-2	*								
SS-5	*	*	*	*	*	*	*	*	
SS-11	*								
SS-12	*	*	*	*	*	*			
SS-16	*	*	*	*	*	*		*	*

TABLE V-2

1983 MONITORING SCHEDULE
GROUND WATER

	Ground-Water Measurements	Inorganics					Organics	
		Cl	SO_4	NH_3	S.C.	pH	DOP	N-N
GW-1	*							
GW-2A	*	*	*	*	*	*	*	*
GW-3	*							
GW-4	*		*	*	*	*		
GW-5	*							
GW-6	*	*	*	*	*	*		
GW-7	*							
GW-8	*							
GW-10	*							
GW-11	*	*	*	*	*	*		
GW-12	*							
GW-13	*			*	*	*		
GW-14	*							
GW-15	*			*	*	*		
GW-16	*							
GW-17S	*							
GW-17D	*							
GW-18S								
GW-18D								
GW-19S	*		*	*	*	*		
GW-19D	*	*	*	*	*	*		
GW-20								
GW-21	*							
GW-22S	*							
GW-22D	*							
GW-23	*							
GW-24	*							
GW-25	*	*	*	*	*	*		
GW-26	*	*	*	*	*	*		

SURFACE WATER

	Flow Measurements	Inorganics					Organics
		Cl	SO_4	NH_3	S.C.	pH	DOP
SS-1	*	*	*	*	*	*	
SS-5	*	*	*	*	*	*	*
SS-12	*	*	*	*	*	*	
SS-16	*	*	*	*	*	*	*

MALCOLM PIRNIE

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APPENDIX A

BORING LOGS

APPENDIX A

SOIL BORING AND MONITORING WELL INSTALLATION

The drilling work was done by Soil Exploration Corporation, of Stow, Massachusetts. In six of the wells, soil borings were performed first, using a 2½ inch hollow stem auger down to bedrock, sampling with a two-inch split spoon. All sampling was performed according to ASTM D 1586-67 specifications. Four to ten feet of bedrock were then cored using NX core. After coring, the bedrock core hole was backfilled with a cement-bentonite slurry. In the four shallow wells, each boring was augered down without sampling to the level at which the well point would be set. A monitoring well was then installed in each of the borings.

The monitoring wells are constructed as follows. Two-inch Schedule 80 flush-jointed, vented PVC pipe with a five foot, 0.01 inch machine-slotted screen was used. The area around the screen was backfilled to at least one foot above the screen with a uniform medium sand. The well was then grouted to the surface with a cement-bentonite slurry. A five-foot long, six-inch diameter protective steel casing with a locking cap, set into a concrete collar, was then placed around each well.

The recovery well was constructed of 12-inch diameter PVC, perforated with ½-inch holes every foot. After excavation with a backhoe, two inches of gravel was placed on the bottom of the hole. The well was set on this gravel layer, then backfilled with additional gravel. A cover and a grating were placed over the well head.

GW-2 was replaced with a six-inch diameter Schedule 80 well with a five foot, 0.01 slot, machine-slotted screen, after the area was excavated with a backhoe. The area around the screen was backfilled with clean sand, then grouted near the surface. A concrete collar was installed around the well head.

The well is constructed of four-inch diameter steel casing with a five-foot 1½-inch drive point. A small area was excavated with a backhoe, then the well was driven into the bottom of the pit and backfilled with the excavated material. The well head is capped.

The drive point wells were made of 1½-inch galvanized steel with five-foot aluminum wrapped screens. The wells were driven in using a jack hammer, then capped with a screw cap.

BORING GW-17D

PROJECT: Olin-Wilmington	PROJECT NO: 284-10-1E00
DATE: 3/3/81	LOCATION: Wilmington, MA
DRILLING CONTRACTOR: Soil Exploration	INSPECTOR: CA Kraemer
DRILLING METHOD: 2½" hollow stem augers	SAMPLING METHOD: 2" split spoon 300 lb. hammer with 24" drop
ELEVATION:	DATUM:

SAMPLE no.	SAMPLE depth	blows per 6"		DEPTH	STRATA	SOIL DESCRIPTION density, color, SOIL, admixtures, moisture, other notes, ORIGIN	WELL CONST.	REMARKS
S-1	0'-2'	1	0			very loose, brown, PEAT, little sand, wet		
		1	0					
S-2	2'-4'	7	11			medium dense, brown, SILT and fine SAND, trace clay, wet		
		15	12					
S-3	4'-6'	9	15	5				
S-4	6'-8'	19	20			Dense, brown-gray, fine to coarse SAND, little silt, trace gravel, wet		
		25	10					
S-5	8'-9.5'	15	100			very dense, gray/brown, SAND, some silts, some gravel, wet, GLACIAL TILL		
		70		10				
						Top of Rock, 13.0 feet		
						Run 1 13.0'-18.0', run 5.0 feet, recover 4.8 feet, 96% recovery		
				15				
						Run 2 18.0'-23.0', run 5.0 feet, recover 3.5, 70% recovery		
				20		Bottom of boring, 23.0 feet		
				25				
				30				
				35				

NOTES: Monitoring well installed. Cement-bentonite slurry from 13.0 to 23.0'. Tip of 5.0 foot 0.010-inch machine slotted well screen set at 12.7 feet and backfilled with uniform medium sand to 7.0 feet. Cement-bentonite slurry from 7.0 feet to ground surface. 5-foot long 6-inch diameter protective steel sleeve, with locking cap, placed on top.

BORING GW-17S

PROJECT: Olin-Wilmington	PROJECT NO: 284-10-1E00
DATE: 3/4/81	LOCATION: Wilmington, MA
DRILLING CONTRACTOR: Soil Exploration	INSPECTOR: CA Kraemer
DRILLING METHOD: 2½" hollow stem augers	SAMPLING METHOD: None taken
ELEVATION:	DATUM:

SAMPLE no.	SAMPLE depth	blows per 6"	DEPTH	STRATA	SOIL DESCRIPTION density, color, SOIL, admixtures, moisture, other notes, ORIGIN	WELL CONST.	REMARKS
			5				
					Bottom of boring 8.0 feet		
			10				
			15				
			20				
			25				
			30				
			35				

NOTES: Monitoring well installed. Tip of 5.0 foot 0.010-inch machine slotted well screen set at 8.0 feet and backfilled with medium uniform sand to 2.0 feet. Cement-bentonite slurry from 2.0 feet to ground surface 5-foot long 6-inch diameter protective steel sleeve, with locking cap placed on top.

BORING GW-18D

PROJECT: Olin-Wilmington	PROJECT NO: 284-10-1E00
DATE: 2/24/81	LOCATION: Wilmington, MA
DRILLING CONTRACTOR: Soil Exploration	INSPECTOR: CA Kraemer
DRILLING METHOD: 2½" hollow stem augers	SAMPLING METHOD: 2" split spoon 300 lb. hammer with 24" drop
ELEVATION:	DATUM:

SAMPLE no.	depth	blows per 6"		DEPTH	STRATA	SOIL DESCRIPTION density, color, SOIL, admixtures, moisture, other notes, ORIGIN	WELL CONST.	REMARKS
S-1	0'-2'	1	0			Very loose, brown, PEAT and SAND, moist		
S-2	2'-4'	12	15			Very dense, tan SAND, some gravel, some silt, moist		
		20	20					
S-3	4'-5'	15	31	5		Very dense, brown/gray, SAND some gravel, some silt, wet, GLACIAL TILL		
S-4	6'-8'	12	24					
		21	22					
S-5	8'-10'	30	28					
		20	20	10				
S-6	11'-13'	11	30					
		50	40					
				15				
				20		Top of rock, 19.9 feet Run 1 20.0 to 25.0 feet, run 5.0 feet recover 3.5 feet 70% recovery		
				25		Run 2 25.0'-26.0', Run 1.0 foot Recover 0.0 feet, 0% recovery		
				30		Bottom of boring, 26.0 feet		
				35				

NOTES: Monitoring well installed. Cement-bentonite slurry from 20.0' to 26.0'. Tip of 5.0 foot 0.010-inch machine slotted well screen set at 19.5feet and backfilled with medium uniform sand. Cement-bentonite slurry from 10.0 feet to ground surface. 5-foot long 6-inch diameter protective steel sleeve, with locking cap, placed on top.

BORING GW-18S

PROJECT: Olin-Wilmington	PROJECT NO: 284-10-1E00
DATE: 2/25/81	LOCATION: Wilmington, MA
DRILLING CONTRACTOR: Soil Exploration	INSPECTOR: CA Kraemer
DRILLING METHOD: 2½" hollow stem augers	SAMPLING METHOD: None taken
ELEVATION:	DATUM:

SAMPLE no.	SAMPLE depth	blows per 6"	DEPTH	STRATA	SOIL DESCRIPTION density, color, SOIL, admixtures, moisture, other notes, ORIGIN	WELL CONST.	REMARKS
			5				
			10		Bottom of boring 10.0 feet		
			15				
			20				
			25				
			30				
			35				

NOTES: Monitoring well installed. Tip of 5.0 foot 0.010-inch machine slotted well screen set at 10.0 feet and backfilled with medium uniform sand to 3.0 feet. Cement-bentonite slurry from 3.0 feet to ground surface 5-foot long 6-inch diameter protective steel sleeve, with locking cap placed on top.

BORING GW-19D

PROJECT: Olin-Wilmington	PROJECT NO: 284-10-1E00
DATE: 2/9/81	LOCATION: Wilmington, MA
DRILLING CONTRACTOR: Soil Exploration	INSPECTOR: CA Kraemer
DRILLING METHOD: 2½" hollow stem augers	SAMPLING METHOD: 2" split spoon 300 lb. hammer with 24" drop
ELEVATION:	DATUM:

SAMPLE no.	SAMPLE depth	blows per 6"	blows per 6"	DEPTH	STRATA	SOIL DESCRIPTION density, color, SOIL, admixtures, moisture, other notes, ORIGIN	WELL CONST.	REMARKS
						Dense, brown, SILT and SAND, little gravel, frozen, FILL		
S-1	2'-4'	1	0			Very loose, light gray, SILT, wet, GYPSUM SLUDGE		
		0	0					
S-2	4'-6'	1	0					
		0	0	5				
S-3	6'-7.5'	1	1			Very loose, brown, SILT and SAND,		
S-4	7.5'-9.0'	2	2			some organics, wet		
		2	12					
S-5	9'-10'	8	100	10		Grading to little gravel		
						Very dense brown/gray, SAND and		
S-6	11'-12.5'	12	25			gravel, little silt, wet, GLACIAL		
S-7	12.5'-13.3'	35	15			TILL		
		100/	.3'					
S-8	14'-14.8'	30		15				
		100/	.3'			Boulder 15'-16.1'		
						Boulder, 16.5'-17.1' and 17.1'-17.8'		
						Boulder 18'-18.8' and 19.3'-19.9'		
				20		Top of rock 20.0 feet		
						Run 1 20.0'-23.0' run 3.0 feet		
						Recover 2.0 feet, 67% recovery		
						Run 2 23.0'-24.3' Run 1.3 feet		
				25		Recover 0.0 feet 0% recovery (Core barrel broke)		
						Bottom of boring 24.3 feet		
				30				
				35				

NOTES: Monitoring well installed. Cement-bentonite slurry from 20.0' to 24.3'. Tip of 5.0 foot 0.010-inch machine slotted well screen set at 19.7 feet and backfilled with medium uniform sand to 10.0 feet. Cement-bentonite slurry from 10.0 feet to ground surface. 5-foot long 6-inch protective steel sleeve, with locking cap, placed on top.

BORING GW-19S

PROJECT: Olin-Wilmington	PROJECT NO: 284-10-1E00
DATE: 2/12/81	LOCATION: Wilmington, MA
DRILLING CONTRACTOR: Soil Exploration	INSPECTOR: CA Kraemer
DRILLING METHOD: 2½" hollow stem augers	SAMPLING METHOD: None taken
ELEVATION:	DATUM:

SAMPLE no.	SAMPLE depth	SAMPLE blows per 6"	DEPTH	STRATA	SOIL DESCRIPTION density, color, SOIL, admixtures, moisture, other notes, ORIGIN	WELL CONST.	REMARKS
			5				
			10		Bottom of boring 10.0 feet		
			15				
			20				
			25				
			30				
			35				

NOTES: Monitoring well installed. Tip of 5.0 foot 0.010-inch machine slotted well screen set at 10.0 feet and backfilled with medium uniform sand to 3.5 feet. Cement-bentonite slurry from 3.5 feet to ground surface. 5-foot long 6-inch diameter protective steel sleeve, with locking cap placed on top.

BORING GW-20

PROJECT: Olin-Wilmington	PROJECT NO: 284-10-1E00
DATE: 2/26/81	LOCATION: Wilmington, MA
DRILLING CONTRACTOR: Soil Exploration	INSPECTOR: CA Kraemer
DRILLING METHOD: 2½" hollow stem augers	SAMPLING METHOD: 2" split spoon 300 lb. hammer with 24" drop
ELEVATION:	DATUM:

SAMPLE no.	SAMPLE depth	blows per 6"		DEPTH	STRATA	SOIL DESCRIPTION density, color, SOIL, admixtures, moisture, other notes, ORIGIN	WELL CONST.	REMARKS
~~S-1~~	~~0'-2'~~	~~1~~	~~0~~			Top soil and roots, 0.0'-1.0 feet		
		4	12			Medium dense, brown, SAND, some gravel, trace silt, moist Grading to dense, SAND and GRAVEL trace silt		
~~S-2~~	2'-4'	25	23					
		17	15					
S-3	4'-5.5'	10	18					
		40		5				
						Very dense, gray/brown, SAND some silt, some gravel, moist, GLACIAL TILL		
				10				
				15		Top of Rock 15.0 feet Run 1, 15.0'-16.5' Run 15. feet Recover 1.0', 67% recovery Run 2, 16.5'-21.5' Run 5.0' Recover 3.9', 68% recovery		
				20				
						Bottom of boring 21.5 feet		
				25				
				30				
				35				

NOTES: Monitoring well installed. Cement-bentonite slurry from 15.0' to 21.5' Tip of 5.0 foot 0.010-inch machine slotted well screen set at 14.7' feet and backfilled with medium uniform sand to 8.0 feet. Cement bentonite slurry from 8.0 feet to ground surface. 5-foot long 6-inch diameter protective steel sleeve, with locking cap, placed on top.

BORING GW-21

PROJECT: Olin-Wilmington	PROJECT NO: 284-10-1E00
DATE: 3/5/81	LOCATION: Wilmington, MA
DRILLING CONTRACTOR: Soil Exploration	INSPECTOR: CA Kraemer
DRILLING METHOD: 2½" hollow stem augers	SAMPLING METHOD: 2" split spoon 300 lb. hammer with 24" drop
ELEVATION:	DATUM:

SAMPLE no.	SAMPLE depth	blows per 6"		DEPTH	STRATA	SOIL DESCRIPTION density, color, SOIL, admixtures, moisture, other notes, ORIGIN	WELL CONST.	REMARKS
S-1	0'-2'	1	0			Very loose, dark brown, PEAT, little sand, wet		
		0	0					
S-2	2'-4'	5	6			Medium dense, brown, SAND, trace silt, wet		
		5	6					
S-3	4'-6'	9	11	5		Dense, brown/gray SAND, some SILT, some gravel, moist GLACIAL TILL		
		12	11					
				10				
				15		Top of Rock 15.0 feet Run 1, 15.0'-17.5' Run 2.5' Recover 2.5', 100% recovery Run 2, 17.5'-20.0' recover 2.0' 80% recovery		
				20		Bottom boring, 20.0 feet		
				25				
				30				
				35				

NOTES: Monitoring well installed. Cement-bentonite slurry from 15.0' to 20.0' Tip of 5.0 foot 0.010-inch machine slotted pipe well screen set at 14.5' feet and backfilled with uniform medium sand to 4.0 feet. Cement-bentonite slurry from 4.0 feet to ground surface. 5-foot long 6-inch protective steel sleeve, with locking cap, placed on top.

BORING GW-22D

PROJECT: Olin-Wilmington	PROJECT NO: 284-10-1E00
DATE: 3/4/81	LOCATION: Wilmington, MA
DRILLING CONTRACTOR: Soil Exploration	INSPECTOR: CA Kraemer
DRILLING METHOD: 2½" hollow stem augers	SAMPLING METHOD: 2" split spoon 300 lb. hammer with 24" drop
ELEVATION:	DATUM:

SAMPLE no.	depth	blows per 6"		DEPTH	STRATA	SOIL DESCRIPTION density, color, SOIL, admixtures, moisture, other notes, ORIGIN	WELL CONST.	REMARKS
S-1	0'-2'	1	2			Loose, brown, SAND, trace silt, wet, MISCELLANEOUS FILL (also contains construction lumber, metal strips, and chemical products)		
		5	6					
S-2	2'-4'	6	5					
		4	4					
S-3	4'-6'	3	2					
		7	8	5				
S-4	6'-8'	8	9					
		14	28					
S-5	8'-10'	8	9					
		14	28	10		Dense brown, fine SAND, little gravel, little silt, wet		
S-6	10'-12'	23	26					
		18	21					
S-7	12'-14'	14	21					
		25	26					
S-8	14'-16'	24	25					
		19	19	15		Dense gray/brown, SAND, some silt, some gravel, moist, GLACIAL TILL		
				20				
				25				
				30				
				35		Top of Rock 36.0 feet Bottom of boring, 36.0 feet		

NOTES: Monitoring well installed. Tip of 5.0 foot 0.010-inch machine slotted well screen set at 35.0' feet and backfilled with uniform medium sand to 15.0 feet. Cement-bentonite slurry from 15.0 feet to ground surface 5-foot long 6-inch diameter protective steel sleeve, with locking cap placed on top.

BORING GW-22S

PROJECT: Olin-Wilmington	PROJECT NO: 284-10-1E00
DATE: 3/5/81	LOCATION: Wilmington, MA
DRILLING CONTRACTOR: Soil Exploration	INSPECTOR: CA Kraemer
DRILLING METHOD: 2½" hollow stem augers	SAMPLING METHOD: None taken
ELEVATION:	DATUM:

SAMPLE no.	SAMPLE depth	SAMPLE blows per 6"	DEPTH	STRATA	SOIL DESCRIPTION density, color, SOIL, admixtures, moisture, other notes, ORIGIN	WELL CONST.	REMARKS
			5				
			10				
			15		Bottom of boring 15.0 feet		
			20				
			25				
			30				
			35				

NOTES: Monitoring well installed. Tip of 5.0 foot 0.010-inch machine slotted well screen set at 15.0 feet and backfilled with medium uniform sand to 8.0 feet. Cement-bentonite slurry from 8.0 feet to ground surface 5-foot long 6-inch diameter protective steel sleeve, with locking cap placed on top.

MALCOLM PIRNIE, INC.

APPENDIX B

LABORATORY SOIL TEST PROCEDURES

MALCOLM PIRNIE

OLIN, WILMINGTON

SUMMARY OF SOILS LABORATORY TEST RESULTS

Boring No.	Sample No.	Depth	Moisture Content (%)	pH	Cation Exchange Capacity (meg/100g)	Soil Description
GW-17D	S-2	2'-4'	14	5.2	5.2	SAND, little silt, trace gravel
GW-17D	S-4	6'-8'	8	6.7	22.7	SAND, some silt, some gravel, SM[1], TILL
GW-18D	S-2	2'-4'	9	4.9	28.2	SAND, some gravel, some silt, SM[1]
GW-18D	S-4	6'-8'	10	5.2	21.5	SAND, some gravel, some silt, TILL
GW-18D	S-6	11'-13'	9	6.7	22.8	SAND, some silt, some gravel, SM[1], TILL
GW-19D	S-6	11'-12.5'	10	5.7	18.6	SAND and GRAVEL, little silt, SM[1], TILL
GW-20	S-2	2'-4'	10	4.7	8.8	SAND, some gravel, trace silt, SM-SP[1]
GW-21	S-2	2'-4'	24	4.3	13.5	SAND, trace silt, SM-SP[1]
GW-22D	S-3	4'-6'	20	7.5	7.1	SAND, trace silt, SP[1]
GW-22D	S-6	10'-12'	12	6.9	5.1	SAND, little silt, little gravel, SM[1]
GW-22D	S-7	12'-14'	10	6.3	7.2	SAND, some silt, some gravel, TILL

1 Unified Soil Classification System

APPENDIX B
LABORATORY SOIL TEST PROCEDURES

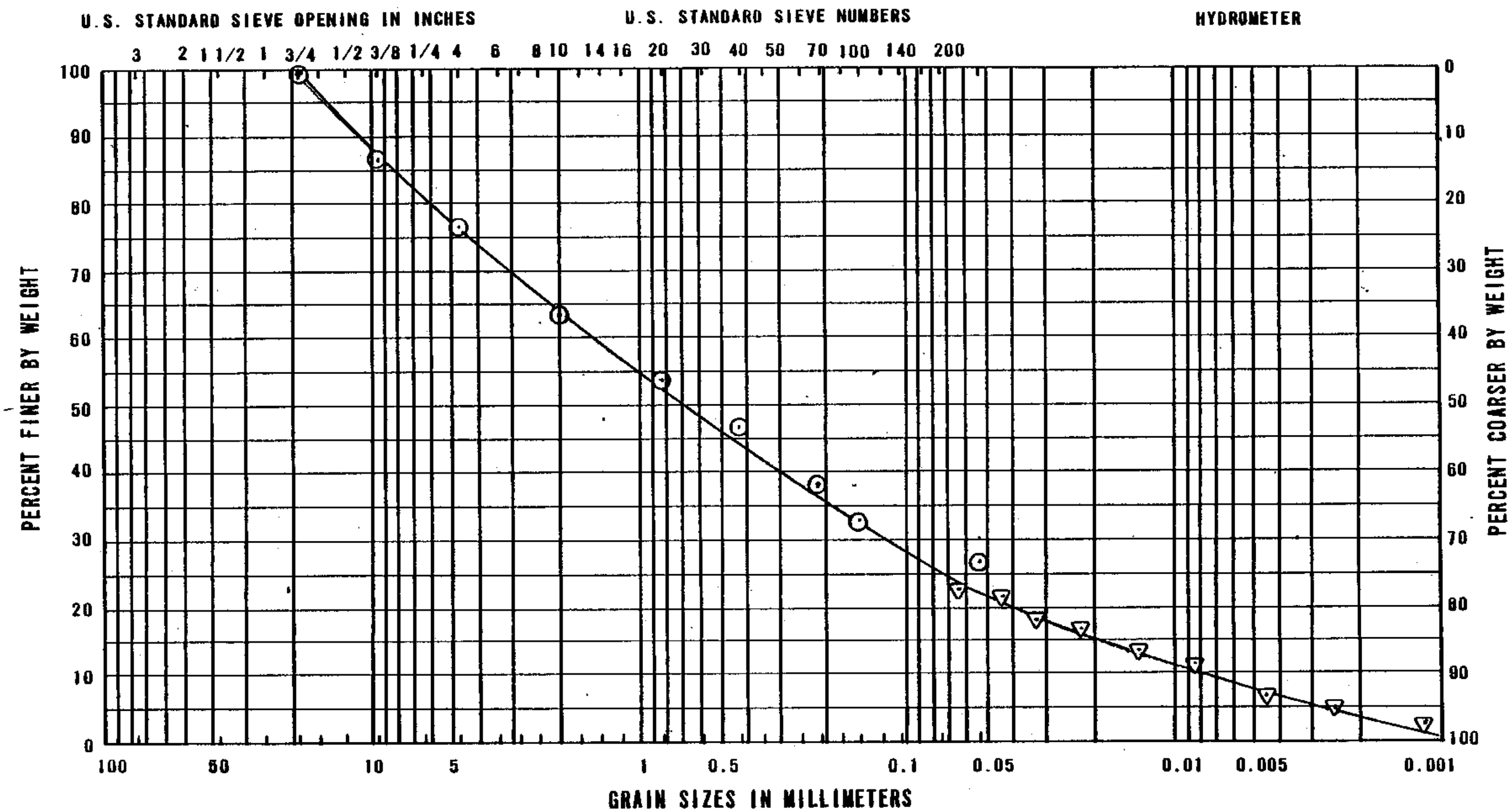
1. Moisture Content: ASTM D 2216-71

2. Grain-size distribution: ASTM D 422-63

3. pH: Glass electrode pH meter

4. CEC: Sodium extraction method

GRAIN SIZE CURVE



UNIFIED SOIL CLASSIFICATION	GRAVEL		SAND			SILT OR CLAY
	Coarse	Fine	Coarse	Medium	Fine	

USDA	GRAVEL	SAND					SILT	CLAY
		Very Coarse	Coarse	Medium	Fine	Very Fine		

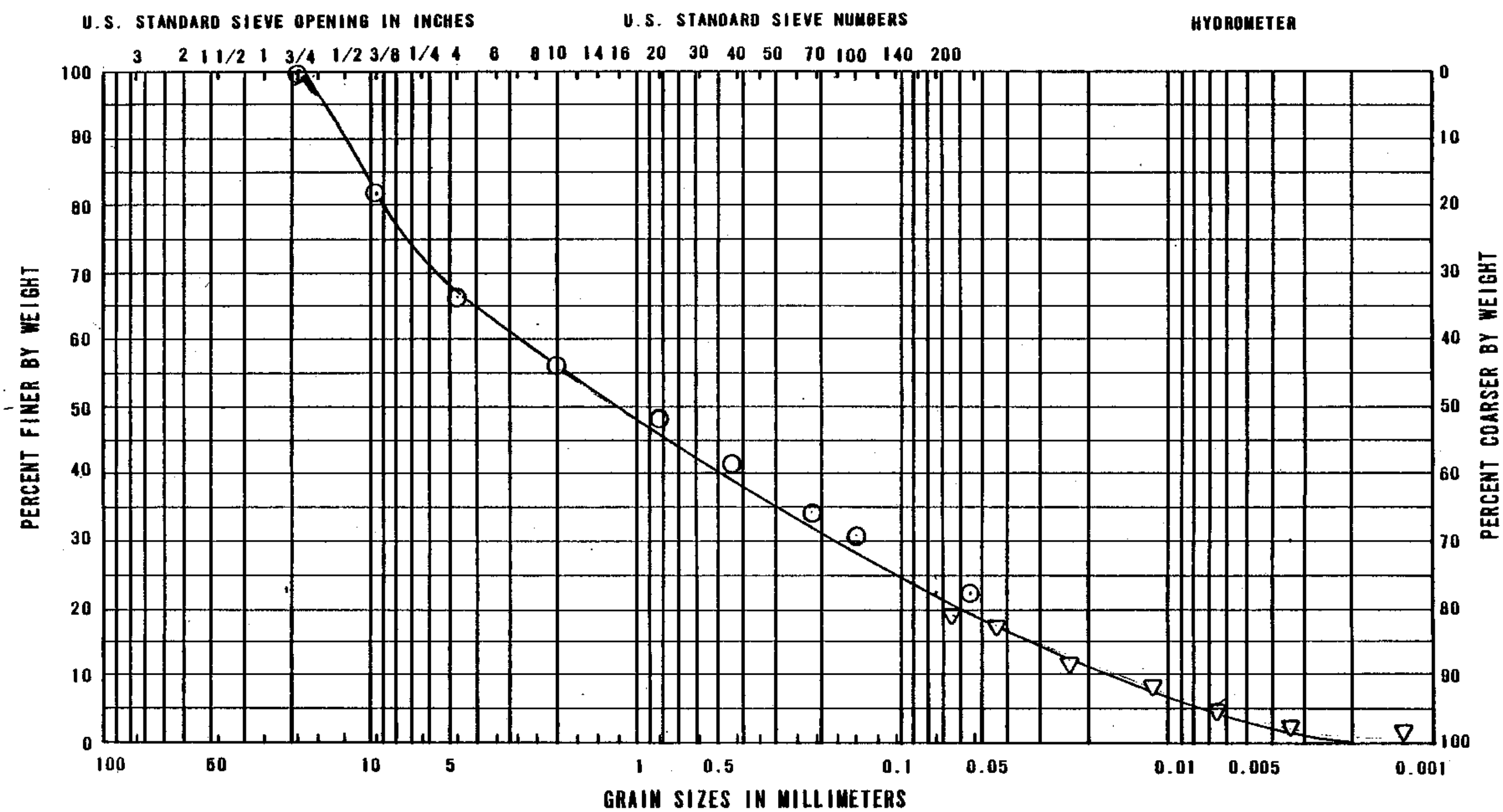
MALCOLM PIRNIE INC.

Olin-Wilmington
284-10-1E00
GW-17
S-4

6'-8'

Figure B-1

GRAIN SIZE CURVE



UNIFIED SOIL CLASSIFICATION	GRAVEL		SAND			SILT OR CLAY
	Coarse	Fine	Coarse	Medium	Fine	

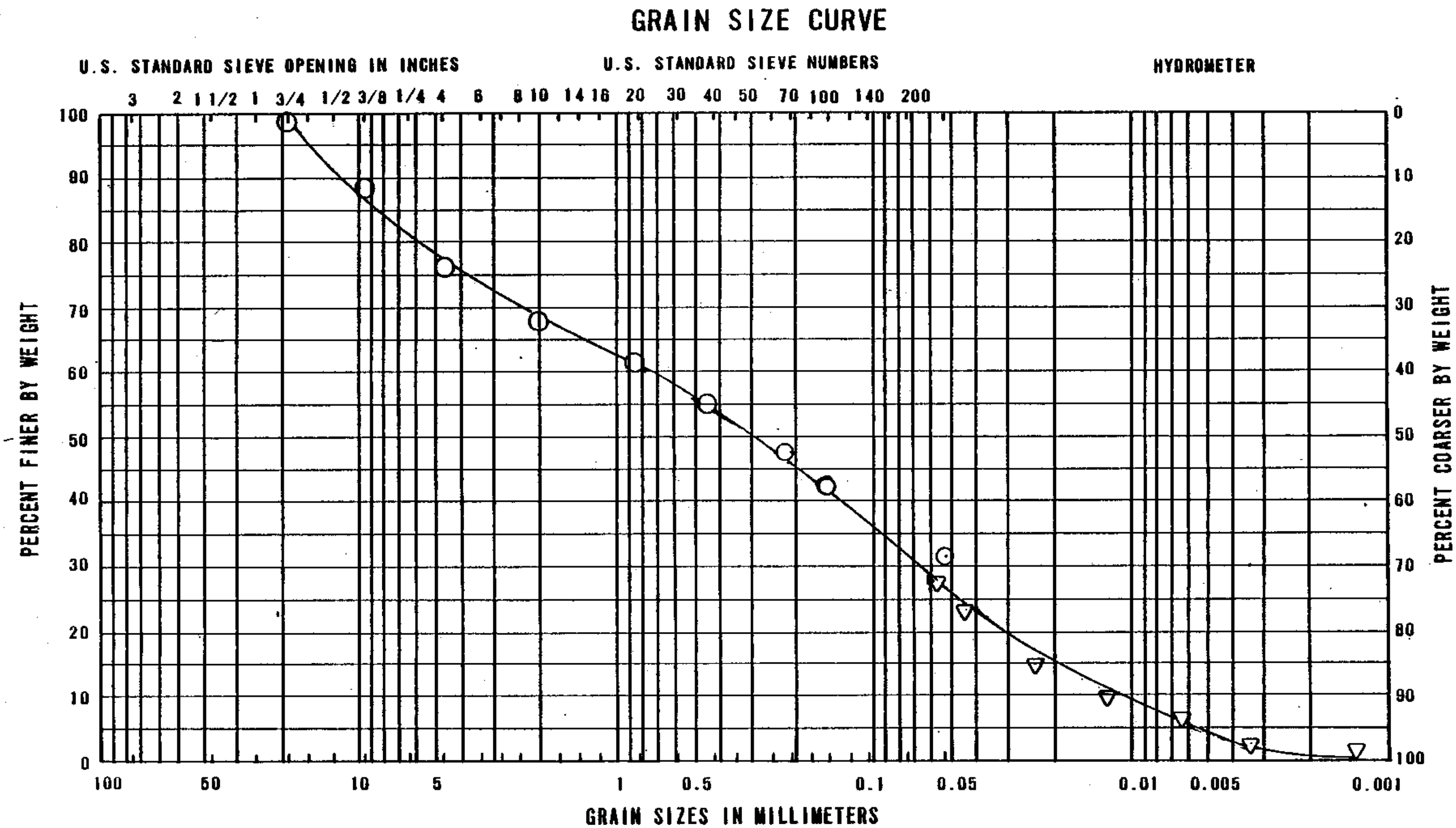
USDA	GRAVEL	SAND					SILT	CLAY
		Very Coarse	Coarse	Medium	Fine	Very Fine		

MALCOLM PIRNIE INC.

Olin-Wilmington
284-10 -1E00
GW-18
S-2

2'-4'

Figure B-2



UNIFIED SOIL CLASSIFICATION	GRAVEL		SAND			SILT OR CLAY
	Coarse	Fine	Coarse	Medium	Fine	

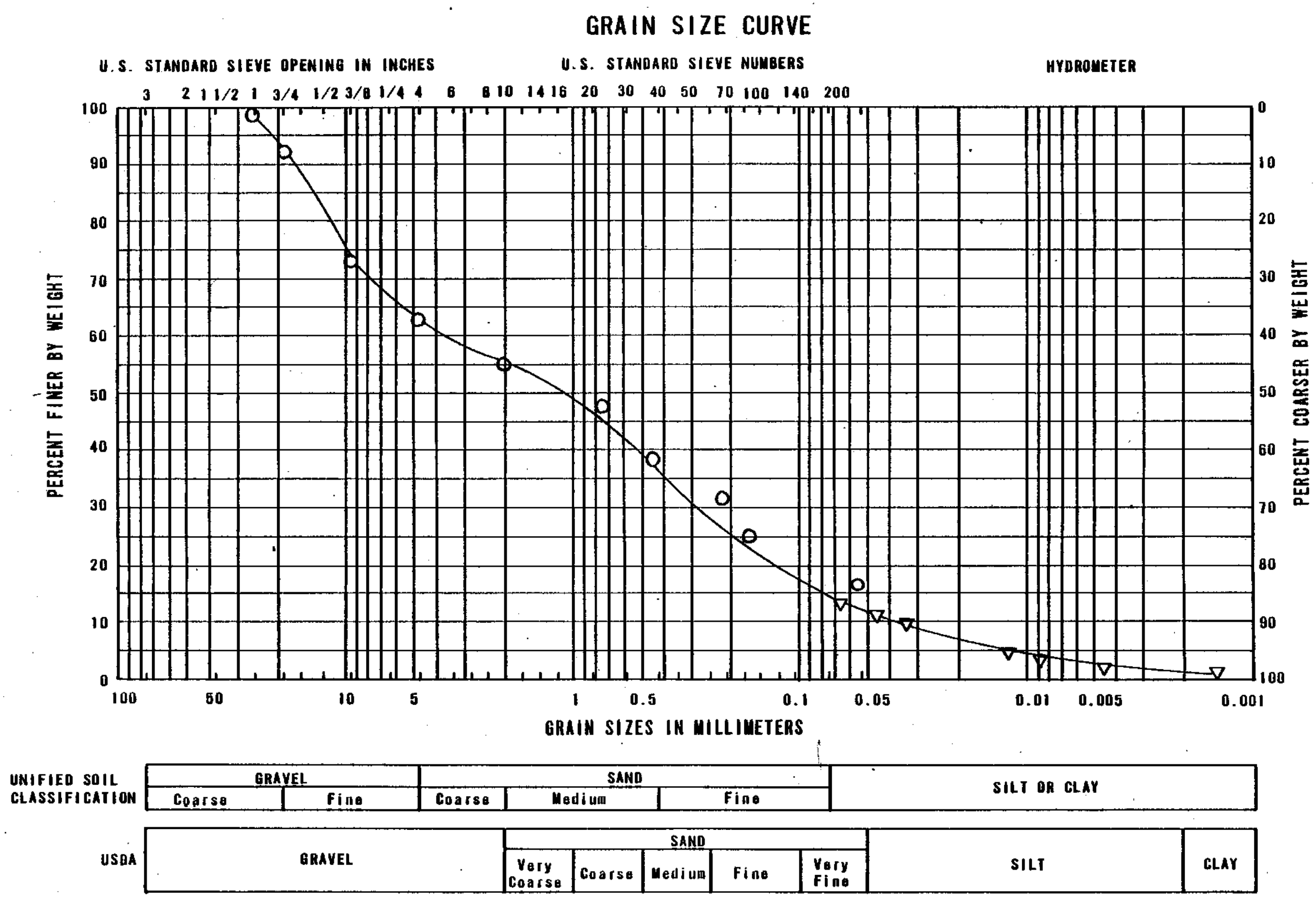
USDA	GRAVEL	SAND					SILT	CLAY
		Very Coarse	Coarse	Medium	Fine	Very Fine		

MALCOLM PIRNIE INC.

Olin-Wilmington
284-10 -1E00
GW-18
S-6

11'-13'

Figure B-3

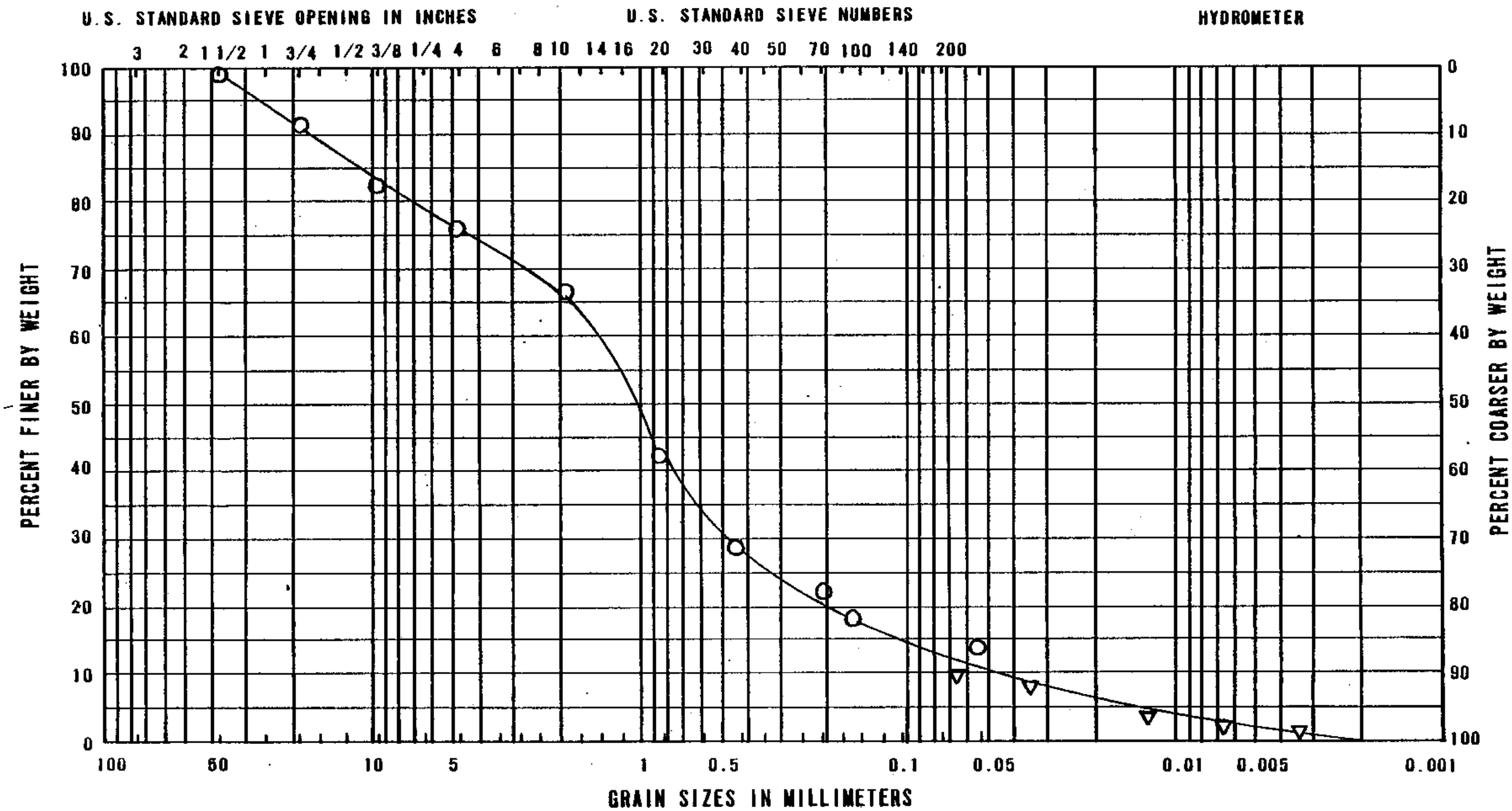


MALCOLM PIRNIE INC.

Olin-Wilmington
284-10 -1E00
GW-19
S-6

Figure B-4

GRAIN SIZE CURVE



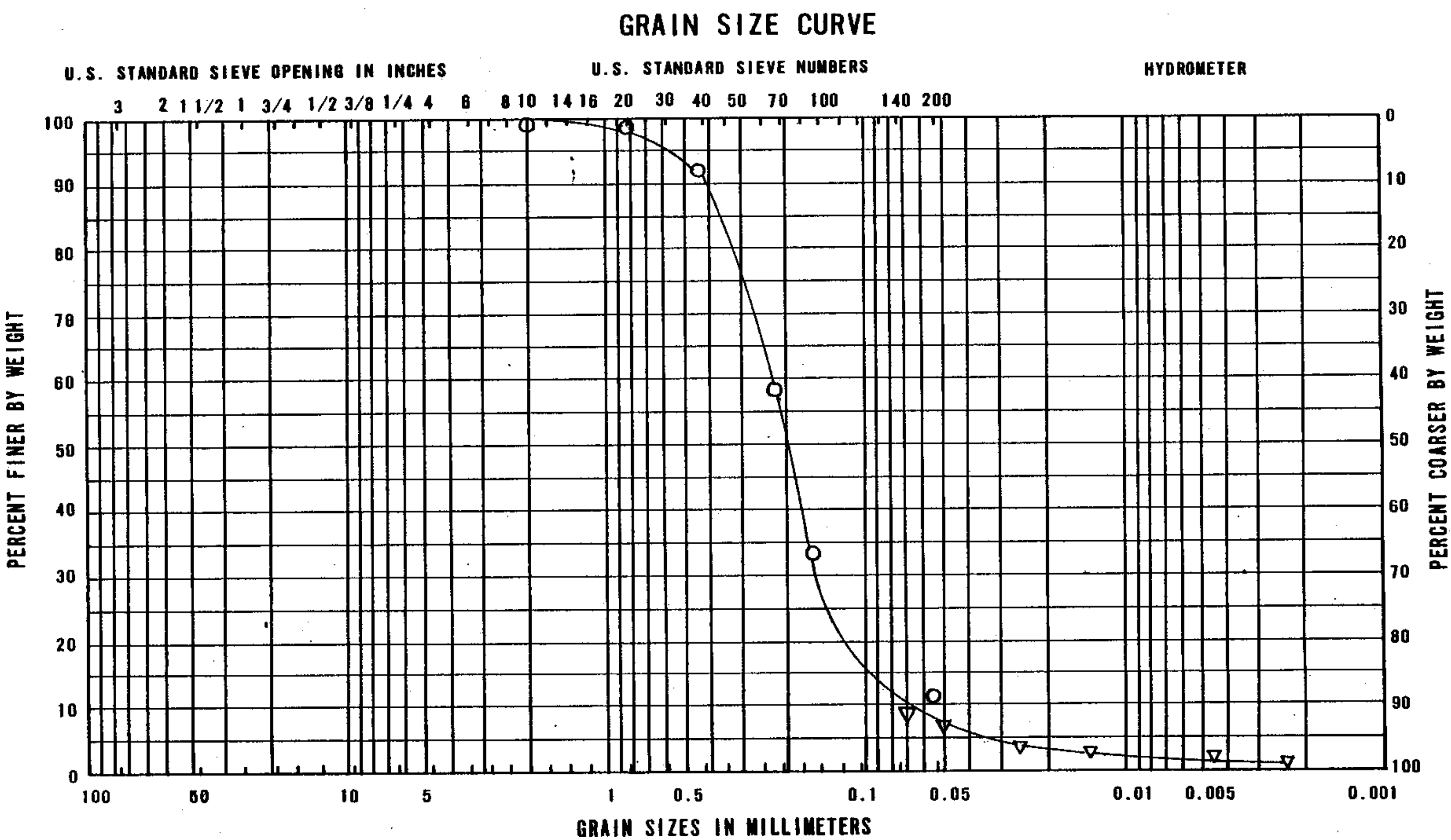
UNIFIED SOIL CLASSIFICATION	GRAVEL		SAND			SILT OR CLAY
	Coarse	Fine	Coarse	Medium	Fine	

USDA	GRAVEL	SAND					SILT	CLAY
		Very Coarse	Coarse	Medium	Fine	Very Fine		

MALCOLM PIRNIE INC.

Olin-Wilmington
284-10-1E00
GW-20
S-2

Figure B-5



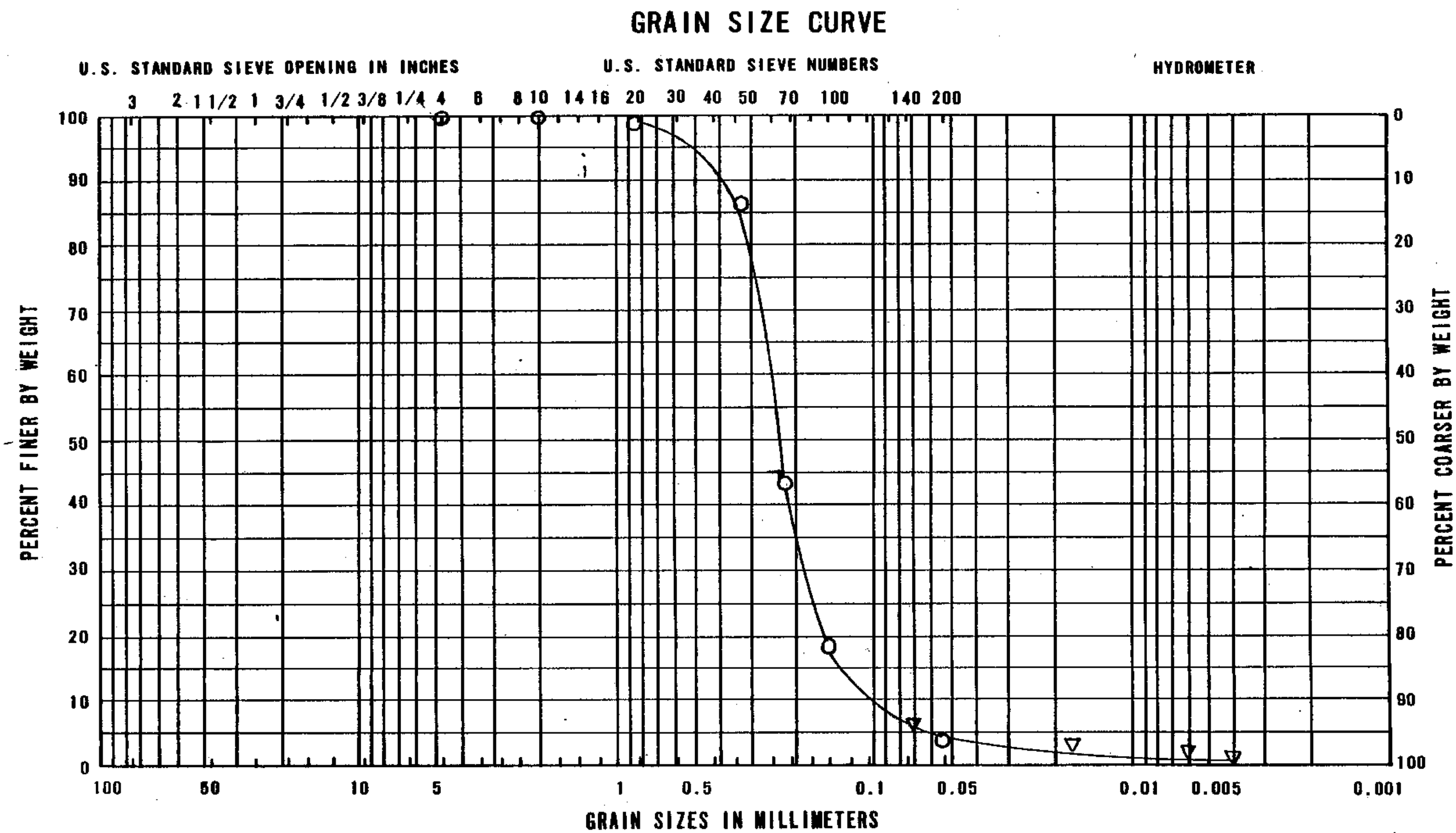
UNIFIED SOIL CLASSIFICATION	GRAVEL		SAND			SILT OR CLAY
	Coarse	Fine	Coarse	Medium	Fine	

USDA	GRAVEL	SAND					SILT	CLAY
		Very Coarse	Coarse	Medium	Fine	Very Fine		

MALCOLM PIRNIE INC.

Olin Wilmington
284-10-1E00
GW-21
S-2

Figure B-6



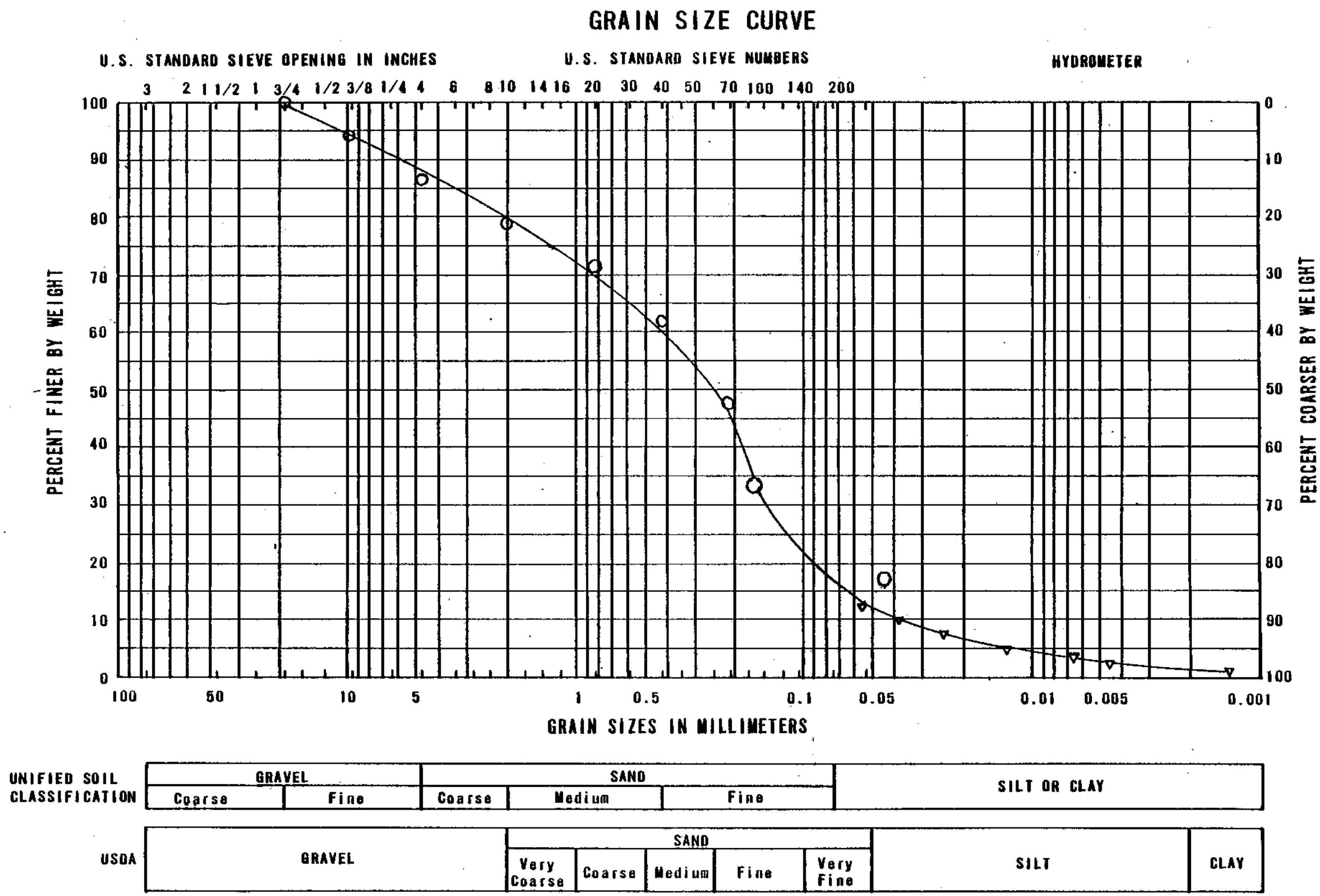
UNIFIED SOIL CLASSIFICATION	GRAVEL		SAND			SILT OR CLAY
	Coarse	Fine	Coarse	Medium	Fine	

USDA	GRAVEL	SAND					SILT	CLAY
		Very Coarse	Coarse	Medium	Fine	Very Fine		

MALCOLM PIRNIE INC.

Olin Wilmington
284-10-1E00
GW-22
S-3
4'-6'

Figure B-7



MALCOLM PIRNIE INC.

Olin-Wilmington
284-10-1E00
GW-22
S-6
10'-12'

Figure B-8

APPENDIX B

LABORATORY SOIL TEST PROCEDURES

TABLE B-1

HYDRAULIC CONDUCTIVITIES OF SOILS BENEATH THE OLIN SITE

WELL	HYDRAULIC CONDUCTIVITY, CM/SEC	SOIL TYPE
GW-1	2×10^{-2}	till
GW-2	9×10^{-3}	sand and till
GW-3	2×10^{-4}	sand and till
GW-4	5×10^{-4}	till
GW-5	6×10^{-3}	till
GW-6	1×10^{-4}	sand and till
GW-7	2×10^{-4}	till
GW-8	2×10^{-2}	till, little sand
GW-10	1×10^{-2}	sand and till
GW-11	5×10^{-4}	sand
GW-12	4×10^{-3}	sand, little till

APPENDIX C

INORGANIC CHEMICAL ANALYSES-GROUND WATER

APPENDIX C
PHYSIOCHEMICAL MEASUREMENTS

pH was measured using a Universal Interloc pH meter. The pH was measured from a sample of fresh well water (after well evacuation) or surface water. The pH meter was standardized after every third pH reading with pH 4 standard solution and pH 10 standard solution.

Disolved oxygen was measured in milligrams per liter (mg/l) with a Yellow Springs dissolved oxygen-temperature meter. The D.O. probe was placed in the well after well evacuation or below the stream surface for measurement. Standardization of the probe was performed after every third measurement, following the standardization procedure on the D.O. meter. The D.O. membrane on the probe was replaced before each sampling period.

Specific conductance was measured in micromhos (umhos) using a Hach spectrophotometer. Standardization of the meter was performed in the Pirnie laboratory before the beginning of each sampling period. Samples were taken from fresh well water (after well evacuation) or surface water.

Temperature was measured in degrees centigrade (°C) with the temperature probe on the dissolved oxygen meter, in the well or stream; and with a field thermometer measured in a fresh sample drawn from the well or stream.

<u>Inorganic Analysis Techniques</u>

1.	Cl^-	Titrimetric; Mercuric Nitrate
2.	$SO_4^=$	Gravimetric; Turbidimetric
3.	NH_3-N	Colorimetric; Distillation Procedure
4.	NO_3-NO_2-N	Colorimetric; Brucine, Spectrophotometric

5.	Total Cr	Atomic Absorption; Chelation-Extraction
6.	Cr^{3+}	Total Cr - hexavalent Cr
7.	Cr^{6+}	Chelation-Extraction
8.	Cd	Atomic Absorption; Direct Aspiration
9.	Pb	Atomic Absorption; Direct Aspiration
10.	Alkalinity	Titrimetric (pH 4.5)

TABLE C-1

PHYSIOCHEMICAL CHARACTERISTICS OF GROUND WATER AT WILMINGTON

Well Number	Specific Conductance, umhos					
	3-81	4-81	5-81	6-81	8-81	12-81
GW-1	475	575	725	600	869	-
GW-2 & 2A	6,750	10,500	1,650	52,000	1,000	1,050
GW-3	1,200	1,100	1,125	2,250	1,225	-
GW-4	3,750	3,000	3,500	6,500	4,000	6,250
GW-5	5,750	4,250	5,000	5,000	3,500	4,975
GW-6	42,100	50,000	44,000	54,000	34,000	-
GW-7	38,100	50,000	35,909	52,000	50,800	-
GW-8	4,300	3,800	3,800	5,500	7,000	-
GW-10	200	1,275	500	2,250	2,968	-
GW-11	1,550	18,500	12,500	14,000	15,750	8,500
GW-12	525	725	480	575	550	-
GW-13	3,250	550	160	125	170	-
GW-14	325	500	600	825	851	-
GW-15	3,500	4,250	4,000	5,750	4,500	-
GW-16	550	275	250	375	650	-
GW-17S	-	2,500	2,500	3,500	4,000	-
GW-17D	7,000	7,000	7,250	9,000	8,000	-
GW-18S	-	-	-	-	-	-
GW-18D	-	9,750	1,550	1,425	950	-
GW-19S	3,000	3,250	3,500	3,500	3,700	-
GW-19D	5,500	3,250	6,000	11,500	15,500	-
GW-20	1,150	1,275	1,875	900	900	-
GW-21	625	950	1,525	1,600	1,750	-
GW-22S	13,750	10,250	8,500	9,000	12,757	-
GW-22D	49,100	66,000	44,000	56,000	39,293	-
GW-23	-	-	-	-	750	-
GW-24	-	-	-	-	13,250	-
GW-25	-	-	-	-	16,000	-
GW-26	-	-	-	-	13,500	17,500

TABLE C-2

PHYSIOCHEMICAL CHARACTERISTICS OF GROUND WATER AT WILMINGTON

Well Number	pH					
	3-81	4-81	5-81	6-81	8-81	12-81
GW-1	6.0	6.2	6.2	6.4	6.2	-
GW-2 & 2A	6.2	5.1	5.3	-	6.5	5.6
GW-3	4.5	5.1	5.9	6.1	4.6	-
GW-4	4.4	5.3	5.1	5.4	5.1	6.3
GW-5	6.4	6.1	6.5	6.4	6.0	6.5
GW-6	4.3	3.3	4.8	5.5	4.7	-
GW-7	4.4	3.0	4.9	4.0	3.8	-
GW-8	3.8	3.5	4.2	5.2	4.5	-
GW-10	3.8	4.1	4.9	6.4	5.5	-
GW-11	10	9.5	9.0	9.4	9.0	7.3
GW-12	5.3	4.9	6.2	6.6	5.4	-
GW-13	6.8	5.1	6.9	7.2	6.3	-
GW-14	6.5	4.9	6.5	6.6	5.8	-
GW-15	6.5	4.8	6.6	7.0	7.1	-
GW-16	6.8	4.4	6.2	5.9	5.5	-
GW-17S	-	6.4	6.1	6.6	5.6	-
GW-17D	6.8	6.0	5.6	5.8	5.9	-
GW-18S	-	-	-	-	-	-
GW-18D	-	11.3	10	9.9	10.4	-
GW-19S	9.5	5.7	5.9	6.4	5.9	-
GW-19D	5.8	6.5	5.5	6.8	6.7	-
GW-20	10.8	10.4	10.4	9.3	10.5	-
GW-21	6.7	5.4	6.8	6.7	6.7	-
GW-22S	9.5	7.6	8.2	7.9	7.6	-
GW-22D	9.5	3.0	5.4	4.3	3.8	-
GW-23	-	-	-	-	6.1	-
GW-24	-	-	-	-	6.8	-
GW-25	-	-	-	-	6.5	-
GW-26	-	-	-	-	4.3	5.1

TABLE C-3

PHYSIOCHEMICAL CHARACTERISTICS OF GROUND WATER AT WILMINGTON

Well Number	Chlorides, mg/l					
	3-81	4-81	5-81	6-81	8-81	12-81
GW-1	72	107	77	123	135	-
GW-2	2129	950	194	-	110	30
GW-3	36	27	26	61	42	-
GW-4	416	438	449	459	465	455
GW-5	450	480	459	490	370	394
GW-6	3122	3090	2807	2880	1899	-
GW-7	3995	4535	4135	3573	4950	-
GW-8	370	368	281	582	720	-
GW-10	18	11	10	230	250	-
GW-11	1190	2240	1633	2040	2524	819
GW-12	62	53	306	102	18	-
W-101						-
GW-13	253	11	10	6125	10	-
GW-14	45	16	306	71	150	-
GW-15	541	512	449	766	340	-
GW-16	65	37	26	5	35	-
GW-17S	-	235	204	225	210	-
GW-17D	591	875	766	510	949	-
GW-18S	-	-	-	-	-	-
GW-18D	-	69	56	163	25	-
GW-19S	94	64	72	102	40	-
GW-19D	601	1046	536	1633	1999	-
GW-20	22	16	179	26	15	-
GW-21	94	107	87	112	110	-
GW-22S	300	480	378	434	730	-
GW-22D	1742	7200	5360	7450	7990	-
GW-23	-	-	-	-	70	-
GW-24	-	-	-	-	2000	-
GW-25	-	-	-	-	2074	-
GW-26	-	-	-	-	1399	1112
Sump-1	-	-	-	-	510	-

TABLE C-4

PHYSIOCHEMICAL CHARACTERISTICS OF GROUND WATER AT WILMINGTON

Well Number	Sulfates, mg/l					
	3-81	4-81	5-81	6-81	8-81	12-81
GW-1	44	28	100	55	36	-
GW-2	1,145	1,990	366	-	1,550	111
GW-3	405	402	384	725	362	-
GW-4	853	934	979	1,883	1,225	1,376
GW-5	1,523	1,500	1,400	2,767	1,075	1,446
GW-6	17,390	18,880	18,560	47,670	1,550	-
GW-7	14,244	16,690	16,080	45,300	1,250	-
GW-8	1,016	1,130	1,030	3,450	2,800	-
GW-10	32	23	27	767	590	-
GW-11	3,096	3,440	2,990	2,900	6,500	1,120
GW-12	54	101	70	64	33	-
GW-13	760	95	6	15	28	-
GW-14	44	35	16	106	80	-
GW-15	88	108	809	105	127	-
GW-16	38	30	20	26	19	-
GW-17S	-	930	863	1,500	875	-
GW-17D	2,215	3,045	2,624	2,624	6,520	3,500
GW-18S	-	-	-	-	-	-
GW-18D	-	60	326	178	122	-
GW-19S	1,726	1,675	1,774	2,530	1,350	-
GW-19D	1,228	1,839	1,265	6,080	3,400	-
GW-20	96	16	12	33	25	-
GW-21	100	64	17	6	11	-
GW-22S	2,911	2,620	1,880	4,330	4,050	-
GW-22D	6,706	27,500	33,846	59,000	26,500	-
GW-23	-	-	-	-	37	-
GW-24	-	-	-	-	4,250	-
GW-25	-	-	-	-	4,860	-
GW-26	-	-	-	-	8,500	7,729
Sump-1	-	-	-	-	2,145	-

TABLE C-5

PHYSIOCHEMICAL CHARACTERISTICS OF GROUND WATER AT WILMINGTON

Well Number	Alkalinity, mg/l 3-81	4-81	5-81	6-81	8-81	12-81
GW-1	54	83	98	89	-	-
GW-2 & 2A	0	28	88	-	-	160
GW-3	12	3	1	10	-	-
GW-4	2	6	0	9	-	4
GW-5	73	75	69	78	-	10
GW-6	0	122	0	148	-	-
GW-7	32	66	0	<1	-	-
GW-8	0	4	0	2	-	-
GW-10	2	2	0	28	-	-
GW-11	2725	3250	2765	3425	-	386
GW-12	41	5	3	<1	-	-
GW-13	67	21	15	17	-	-
GW-14	34	55	28	36	-	-
GW-15	554	700	738	1133	-	-
GW-16	89	28	6	20	-	-
GW-17S	-	50	34	70	-	-
GW-17D	-	215	170	102	-	-
GW-18S	-	-	-	-	-	-
GW-18D	-	300	180	335	-	-
GW-19S	311	263	122	236	-	-
GW-19D	246	506	238	955	-	-
GW-20	226	325	168	200	-	-
GW-21	32	242	195	132	-	-
GW-22S	1245	600	448	505	-	-
GW-22D	17	<1	0	<1	-	-
GW-23	-	-	-	-	-	-
GW-24	-	-	-	-	-	-
GW-25	-	-	-	-	-	-
GW-26	-	-	-	-	-	98

TABLE C-6

PHYSIOCHEMICAL CHARACTERISTICS OF GROUND WATER AT WILMINGTON

Well Number	NH_3-N, mg/l					
	3-81	4-81	5-81	6-81	8-81	12-81
GW-1	3	8	11	6	2	-
GW-2 & 2A	175	574	133	-	9	35
GW-3	46	75	29	48	36	-
GW-4	126	145	134	140	179	171
GW-5	125	176	157	134	114	129
GW-6	<1	3780	3878	5660	2489	-
GW-7	190	2638	3101	1318	3133	-
GW-8	158	226	210	384	377	-
GW-10	3	61	62	140	108	-
GW-11	729	1854	2051	2002	2458	476
GW-12	6	9	8	4	1	-
GW-13	130	26	11	7	5	-
GW-14	4	10	3	7	5	-
GW-15	167	182	135	333	350	-
GW-16	13	22	4	2	4	-
GW-17S	-	46	48	45	56	-
GW-17D	182	315	336	358	325	-
GW-18S	-	-	-	-	-	-
GW-18D	-	19	11	12	<1	-
GW-19S	83	114	126	130	108	-
GW-19D	239	609	353	974	1204	-
GW-20	1	11	21	1	1	-
GW-21	4	39	21	7	3	-
GW-22S	314	675	427	490	1081	-
GW-22D	192	4102	2757	2340	2545	-
GW-23	-	-	-	-	8	-
GW-24	-	-	-	-	1204	-
GW-25	-	-	-	-	1246	-
GW-26	-	-	-	-	991	126

TABLE C-7

PHYSIOCHEMICAL CHARACTERISTICS OF GROUND WATER AT WILMINGTON

Well Number	(NO_3+NO_2)-N, mg/l 3-81	4-81	5-81	6-81	8-81	12-81
GW-1	2.1	0.9	1.8	1.2	1.6	-
GW-2 & 2A	87.7	35.3	4.0	-	9.1	0.2
GW-3	8.7	13.3	14	26.9	16.8	-
GW-4	7.0	6.3	7.1	6.6	4.6	4.6
GW-5	12	8.9	7.5	0.1	0.8	1.5
GW-6	56.7	57.1	23.8	214	33.2	-
GW-7	42.4	21.7	31.5	43.2	34.6	-
GW-8	57.7	45.0	42.2	66.6	50.1	-
GW-10	6.9	8.4	8.8	16.0	12.4	-
GW-11	1.1	0.6	1.5	1.0	1.3	2.1
GW-12	3.0	2.6	0.5	4.6	2.5	-
GW-13	12.2	6.7	2.0	10.1	3.7	-
GW-14	4.6	4.8	0.6	7.7	4.1	-
GW-15	4.1	0.7	2.6	2.0	2.4	-
GW-16	0.2	2.8	2.6	5.8	3.7	-
GW-17S	-	6.1	3.2	1.6	3.0	-
GW-17D	7.5	9.2	8.7	20.2	13.0	-
GW-18S	-	-	-	-	-	-
GW-18D	-	10.6	11.3	15.2	11.9	-
GW-19S	1.0	1.3	2.2	3.0	2.4	-
GW-19D	0.2	0.4	1.6	1.8	2.0	-
GW-20	0.5	1.2	1.3	1.2	1.2	-
GW-21	2.8	2.0	1.0	0.9	1.0	-
GW-22S	16.5	163	246	403	298	-
GW-22D	445	393	75.5	107	85.8	-
GW-23	-	-	-	-	2.6	-
GW-24	-	-	-	-	3.2	-
GW-25	-	-	-	-	1.2	-
GW-26	-	-	-	-	58.6	40.6

TABLE C-8

PHYSIOCHEMICAL CHARACTERISTICS OF GROUND WATER AT WILMINGTON

Well Number	Chromium + 6, mg/l 3-81*	4-81	5-81	6-81	8-81	12-81
GW-1	0.05	0.01	BDL	0.02	BDL	-
GW-2 & 2A	0.10	0.01	BDL	-	BDL	BDL
GW-3	0.29	BDL	BDL	-	-	-
GW-4	0.05	BDL	BDL	0.01	BDL	BDL
GW-5	0.10	BDL	BDL	BDL	-	BDL
GW-6	0.82	BDL	BDL	BDL	BDL	-
GW-7	60.0	0.01	0.01	0.01	BDL	-
GW-8	0.08	BDL	BDL	BDL	-	-
GW-10	0.02	BDL	BDL	BDL	-	-
GW-11	0.70	BDL	0.01	0.01	BDL	BDL
GW-12	0.06	0.01	BDL	0.01	BDL	-
GW-13	0.15	BDL	BDL	BDL	-	-
GW-14	0.05	0.01	BDL	BDL	0.01	-
GW-15	0.20	0.03	BDL	BDL	-	-
GW-16	0.15	BDL	BDL	BDL	-	-
GW-17S	-	BDL	BDL	0.01	0.01	-
GW-17D	3.22	BDL	0.02	0.04	BDL	-
GW-18S	-	-	-	-	-	-
GW-18D	-	0.36	BDL	0.01	BDL	-
GW-19S	4.08	BDL	0.04	0.05	0.01	-
GW-19D	11.80	0.01	0.04	0.06	BDL	-
GW-20	0.02	0.39	BDL	BDL	BDL	-
GW-21	0.15	0.01	0.01	BDL	BDL	-
GW-22S	103.0	0.01	BDL	BDL	BDL	-
GW-22D	0.22	0.01	0.02	0.01	BDL	-
GW-23	-	-	-	-	BDL	-
GW-24	-	-	-	-	-	-
GW-25	-	-	-	-	-	-
GW-26	-	-	-	-	-	BDL

*Total metal - sample acidified.
Detection Limit: 0.01 mg/l

TABLE C-9

PHYSIOCHEMICAL CHARACTERISTICS OF GROUND WATER AT WILMINGTON

Well Number	Chromium + 3, mg/l					
	3-81*	4-81	5-81	6-81	8-81	12-81
GW-1	-	<0.05	<0.04	≦0.03	≦0.04	-
GW-2 & 2A	-	<0.05	<0.04	-	≦0.04	<0.05
GW-3	-	<0.05	<0.04	<0.04	-	-
GW-4	-	<0.05	<0.04	≦0.04	<0.04	<0.05
GW-5	-	<0.05	<0.04	<0.04	<0.04	<0.05
GW-6	-	<0.05	≦0.43	≦0.38	≦0.1	-
GW-7	-	<0.05	15.85	11.97	≦11.13	-
GW-8	-	<0.05	<0.04	<0.04	-	-
GW-10	-	<0.05	<0.04	<0.04	-	-
GW-11	-	<0.05	0.02	≦0.04	≦0.29	<0.04
GW-12	-	<0.05	<0.04	≦0.04	<0.04	-
GW-13	-	<0.05	<0.04	<0.04	-	-
GW-14	-	<0.05	<0.04	<0.04	≦0.04	-
GW-15	-	<0.05	<0.04	<0.04	-	-
GW-16	-	<0.05	<0.04	<0.04	-	-
GW-17S	-	<0.05	<0.04	≦0.04	≦0.04	-
GW-17D	-	<0.05	<0.04	0.08	≦0.71	-
GW-18S	-	-	-	-	-	-
GW-18D	-	≦0.01	<0.04	≦0.04	<0.04	-
GW-19S	-	<0.05	<0.04	<0.04	<0.04	-
GW-19D	-	<0.05	<0.04	0	≦0.08	-
GW-20	-	<0.01	<0.04	<0.04	<0.04	-
GW-21	-	<0.05	<0.04	≦0.11	<0.04	-
GW-22S	-	<0.05	<0.04	<0.04	<0.04	-
GW-22D	-	11.12	16.25	12.69	11.13	-
GW-23	-	-	-	-	<0.04	-
GW-24	-	-	-	-	-	-
GW-25	-	-	-	-	-	-
GW-26	-	-	-	-	-	<0.05

TABLE C-10

PHYSIOCHEMICAL CHARACTERISTICS OF GROUND WATER AT WILMINGTON

Well Number	Cadmium, mg/l 3-81*	4-81	5-81	6-81	8-81	12-81
GW-1	<0.01	BDL	BDL	BDL	BDL	-
GW-2 & 2A	<0.01	BDL	BDL	-	BDL	BDL
GW-3	<0.01	BDL	BDL	BDL	-	-
GW-4	0.01	0.01	0.02	BDL	BDL	BDL
GW-5	<0.01	BDL	BDL	BDL	-	BDL
GW-6	<0.01	0.04	0.05	0.02	0.02	-
GW-7	0.02	0.06	0.06	0.05	0.02	-
GW-8	<0.01	BDL	BDL	BDL	-	-
GW-10	<0.01	BDL	BDL	BDL	-	-
GW-11	<0.01	BDL	BDL	BDL	BDL	BDL
GW-12	<0.01	BDL	BDL	BDL	BDL	-
GW-13	<0.01	BDL	BDL	BDL	-	-
GW-14	<0.01	BDL	BDL	BDL	BDL	-
GW-15	<0.01	BDL	BDL	BDL	-	-
GW-16	<0.01	BDL	BDL	BDL	-	-
GW-17S	-	0.02	0.02	BDL	BDL	-
GW-17D	<0.01	0.02	0.03	0.01	0.02	-
GW-18S	-	-	-	-	-	-
GW-18D	-	BDL	0.02	BDL	0.02	-
GW-19S	<0.01	BDL	0.03	BDL	0.02	-
GW-19D	<0.01	BDL	BDL	BDL	0.02	-
GW-20	<0.01	BDL	BDL	BDL	0.02	-
GW-21	<0.01	BDL	BDL	BDL	0.02	-
GW-22S	<0.01	BDL	0.02	BDL	0.02	-
GW-22D	<0.01	0.10	0.09	0.08	0.09	-
GW-23	-	-	-	-	BDL	-
GW-24	-	-	-	-	-	-
GW-25	-	-	-	-	-	-
GW-26	-	-	-	-	-	BDL

*Total metal - sample acidified.

Detection Limit: 0.01 mg/l

TABLE C-11

PHYSIOCHEMICAL CHARACTERISTICS OF GROUND WATER AT WILMINGTON

Well Number	Lead, mg/l					
	3-81*	4-81	5-81	6-81	8-81	12-81
GW-1	<0.10	<0.10	<0.04	<0.05	<0.05	-
GW-2 & 2A	<0.20	<0.10	<0.04	-	<0.05	<0.05
GW-3	<0.10	<0.10	<0.04	<0.04	-	-
GW-4	<0.10	<0.10	<0.04	<0.04	<0.05	<0.05
GW-5	<0.10	<0.10	<0.04	<0.04	0.24	<0.05
GW-6	0.40	0.40	0.22	0.28	0.28	-
GW-7	0.30	0.30	0.16	0.16	<0.05	-
GW-8	0.20	<0.10	<0.04	<0.04	-	-
GW-10	<0.10	<0.10	<0.04	<0.04	-	-
GW-11	<0.10	0.10	<0.04	<0.04	<0.05	<0.05
GW-12	<0.10	<0.10	<0.04	<0.04	<0.05	-
GW-13	0.10	<0.10	<0.04	<0.04	-	-
GW-14	<0.10	<0.10	<0.04	<0.04	<0.050	-
GW-15	<0.10	<0.10	<0.04	<0.04	-	-
GW-16	<0.10	<0.10	<0.04	<0.04	-	-
GW-17S	-	0.10	0.05	<0.04	<0.05	-
GW-17D	0.10	0.10	0.11	<0.09	0.08	-
GW-18S	-	-	-	-	-	-
GW-18D	-	<0.10	<0.04	<0.04	<0.05	-
GW-19S	0.10	0.10	<0.04	<0.04	<0.05	-
GW-19D	0.10	<0.10	<0.04	<0.04	<0.05	-
GW-20	<0.10	<0.10	<0.04	<0.04	<0.05	-
GW-21	0.50	<0.10	<0.04	<0.04	<0.05	-
GW-22S	0.20	<0.10	0.05	<0.04	<0.05	-
GW-22D	<0.10	<0.10	0.28	0.46	0.4	-
GW-23	-	-	-	-	<0.05	-
GW-24	-	-	-	-	-	-
GW-25	-	-	-	-	-	
GW-26	-	-	-	-	-	<0.05

*Total metal - sample acidified.

TABLE C-12

PHYSIOCHEMICAL CHARACTERISTICS OF GROUND WATER AT WILMINGTON

Well Number	Dissolved Oxygen, mg/l					
	3-81	4-81	5-81	6-81	8-81	12-81
GW-1	-	1.8	2.0	3.2	-	-
GW-2 & 2A	-	1.8	2.2	-	-	-
GW-3	-	4.0	3.2	1.9	-	-
GW-4	-	3.2	3.0	1.4	-	-
GW-5	-	5.2	2.6	2.5	-	-
GW-6	-	2.6	2.8	2.0	-	-
GW-7	-	4.6	3.0	2.4	-	-
GW-8	-	1.5	2.8	5.0	-	-
GW-10	-	4.9	3.6	2.7	-	-
GW-11	-	1.9	2.0	1.7	-	-
GW-12	-	1.6	3.1	1.4	-	-
GW-13	-	1.4	2.8	4.5	-	-
GW-14	-	6.4	6.8	2.8	-	-
GW-15	-	2.1	1.5	1.8	-	-
GW-16	-	1.4	6.8	3.5	-	-
GW-17S	-	3.2	5.4	4.8	-	-
GW-17D	-	5.2	2.3	1.8	-	-
GW-18S	-	-	-	-	-	-
GW-18D	-	5.7	5.4	3.2	-	-
GW-19S	-	3.2	3.0	1.8	-	-
GW-19D	-	4.2	5.8	1.6	-	-
GW-20	-	4.4	3.3	4.7	-	-
GW-21	-	1.7	4.0	1.8	-	-
GW-22S	-	1.7	2.0	1.7	-	-
GW-22D	-	3.4	7.8	2.4	-	-
GW-23	-	-	-	-	-	-
GW-24	-	-	-	-	-	-
GW-25	-	-	-	-	-	-
GW-26	-	-	-	-	-	-

TABLE C-13

PHYSIOCHEMICAL CHARACTERISTICS OF GROUND WATER AT WILMINGTON

Well Number	Temperature, °C					
	3-81	4-81	5-81	6-81	8-81	12-81
GW-1	9	11	12	11.5	17.5	-
GW-2 & 2A	7	10.5	15	-	18	13
GW-3	7	8.5	13	13	20	-
GW-4	7	8	10.5	11.5	18	11
GW-5	5	8	13	14.5	19	10
GW-6	8	9	12	10	-	-
GW-7	6.5	8	13	12.5	18	-
GW-8	6	7.5	11	12.5	-	-
GW-10	6.5	8.5	12	13	18	-
GW-11	8	7	12	14	19	11.5
GW-12	6	7.5	11	13	17.5	-
GW-13	9	9.5	12.5	13.5	21	-
GW-14	9	7.5	15.5	16	19	-
GW-15	12	14.5	17	17	17	-
GW-16	7	10.5	14.5	15	21	-
GW-17S	-	8.5	11	12	16	-
GW-17D	7	8	10.5	11	11	-
GW-18S	-	-	-	-	-	-
GW-18D	-	7	15	11.5	16	-
GW-19S	7	8	12	13	19	-
GW-19D	8	10	12	11.5	14.5	-
GW-20	6.5	7	9.5	13	17	-
GW-21	7.5	8.5	12	13	18	-
GW-22S	5	9	12	12.5	22	-
GW-22D	8	9	12.5	11.5	15.5	-
GW-23	-	-	-	-	19	-
GW-24	-	-	-	-	-	-
GW-25	-	-	-	-	21	-
GW-26	-	-	-	-	-	12

APPENDIX D

INORGANIC CHEMICAL ANALYSES-SURFACE WATER

TABLE D-1

SURFACE WATER CHEMICAL ANALYSES

Well Number	pH					
	3-81	4-81	5-81	6-81	8-81	12-81
SS-1	6.2	6.8	6.0	6.7	5.9	7.1
SS-1A	-	-	-	-	6.2	-
SS-2	-	-	-	-	8.6	-
SS-5	6.5	6.7	7.1	6.5	7.1	7.4
SS-11	6.1	5.1	5.6	6.9	6.5	-
SS-12	6.1	6.1	5.6	6.6	6.7	6.0
SS-16	6.1	5.8	6.5	6.4	6.6	6.8
SS-N-A	-	-	-	-	-	-
SS-N-B	-	-	-	-	-	-
SS-N-C	-	-	-	-	-	-
SS-N-D	-	-	-	-	5.7	-
SS-N-E	-	-	-	-	-	-
SS-N-F	-	-	-	-	-	-
SS-N-G	-	-	-	-	-	-
LAG-1(SOLID)	-	-	-	-	-	-
LAG-1(LIQUID)	-	-	-	-	9.6	-
LAG-2(LIQUID)	-	-	-	-	8.7	-
UREA TANK SEWER	-	-	-	-	8.5	-
TOWN SEWER	-	-	-	-	-	-
SUMP-1	-	-	-	-	4.5	-

TABLE D-2

SURFACE WATER CHEMICAL ANALYSES

Well Number	Specific Conductance, umhos					
	3-81	4-81	5-81	6-81	8-81	12-81
SS-1	425	400	825	325	290	575
SS-1A	-	-	-	-	575	-
SS-2	-	-	-	-	4,500	
SS-5	6,000	5,000	8,000	7,000	950	950
SS-11	550	375	475	1,050	950	-
SS-12	7,500	6,700	5,500	5,000	5,926	4,250
SS-16	1,450	1,000	1,000	1,150	1,000	775
SS-N-A	-	-	-	-	-	-
SS-N-B	-	-	-	-	-	-
SS-N-C	-	-	-	-	-	-
SS-N-D	-	-	-	4,250	-	-
SS-N-E	-	-	-	-	-	-
SS-N-F	-	-	-	-	-	-
SS-N-G	-	-	-	-	-	-
LAG-1(SOLID)	-	-	-	-	-	-
LAG-1(LIQUID)	-	-	-	16,000	-	-
LAG-2(LIQUID)	-	-	-	58,000	-	-
UREA TANK SEWER	-	-	-	725	-	-
TOWN SEWER	-	-	-	-	-	-
SUMP-1	-	-	-	5,500	-	-

TABLE D-3

SURFACE WATER CHEMICAL ANALYSES

Well Number	Chlorides, mg/l 3-81	4-81	5-81	6-81	8-81	12-81
SS-1	51	43	36	41	50	48
SS-2	-	-	140	225	225	-
SS-5	440	475	592	500	100	81
SS-11	73	43	56	51	100	-
SS-12	892	619	562	459	360	182
SS-16	154	128	117	92	100	35
SS-N-A	-	-	-	414	50	-
SS-N-B	-	-	-	85	85	-
SS-N-C	-	-	-	64	70	-
SS-N-D	-	-	-	692	380	-
SS-N-E	-	-	-	64	80	-
SS-N-F	-	-	-	213	160	-
SS-N-G	-	-	-	<5	-	-
LAG-1(SOLID)	-	-	-	4902*	-	-
LAG-1(LIQUID)	-	-	-	4898	-	-
LAG-2(LIQUID)	-	-	-	5048	-	-

* mg/kg

TABLE D-4

SURFACE WATER CHEMICAL ANALYSES

Well Number	Sulfates, mg/l 3-81	4-81	5-81	6-81	8-81	12-81
SS-1	8	10	12	32	24	22
SS-2	-	-	222	3050	14	-
SS-5	1494	1337	1450	4220	138	131
SS-11	30	40	28	83	66	-
SS-12	2445	1913	1817	2620	1220	420
SS-16	179	191	120	222	120	100
SS-N-A	-	-	-	3125	155	-
SS-N-B	-	-	-	133	78	-
SS-N-C	-	-	-	60	51	-
SS-N-D	-	-	-	4167	1750	-
SS-N-E	-	-	-	89	73	-
SS-N-F	-	-	-	925	135	-
SS-N-G	-	-	-	24	-	-
LAG-1(SOLID)	-	-	-		333,333*	-
LAG-1(LIQUID)	-	-	-		15,800	-
LAG-2(LIQUID)	-	-	-		19,750	-

*mg/kg

TABLE D-5

SURFACE WATER CHEMICAL ANALYSES

Well Number	NH_3 - N, mg/l					
	3-81	4-81	5-81	6-81	8-81	12-81
SS-1	2	4	2	1	<1	2
SS-1A	-	-	-	-	1	-
SS-2	-	-	33	290	239	-
SS-5	255	376	476	535	28	31
SS-11	13	7	4	17	3	-
SS-12	374	390	468	347	203	111
SS-16	52	43	45	22	18	16
SS-N-A	-	408	551	377	28	-
SS-N-B	-	39	25	16	15	-
SS-N-C	-	20	3	2	6	-
SS-N-D	-	1022	1306	1127	287	-
SS-N-E	-	38	22	11	16	-
SS-N-F	-	471	448	185	52	-
SS-N-G	-	-	-	14	-	-
LAG-1(SOLID)	-	-	-	-	17*	-
LAG-1(LIQUID)	-	-	-	-	1232	-
LAG-2(LIQUID)	-	-	-	-	6671	-
UREA TANK	-	-	-	-	28	-
SEWER	-	-	-	-	15	-
SUMP-1	-	-	-	-	33	-

*mg/kg

TABLE D-6

SURFACE WATER CHEMICAL ANALYSES

Well Number	$(NO_3 + NO_2)$-N, mg/l 3-81	4-81	5-81	6-81	8-81	12-81
SS-1	2.1	1.9	0.9	1.9	1.5	1.0
SS-1A	-	-	-	-	0.9	-
SS-2	-	-	4.1	26.9	12.2	-
SS-5	7.2	3.5	2.7	4.7	3.5	2.7
SS-11	2.1	0.5	0.6	3.4	2.0	-
SS-12	5.4	5.0	3.9	6.8	4.9	3.3
SS-16	6.0	4.3	2.0	4.1	3.0	4.5
SS-N-A	-	4.3	5.1	5.8	1.4	-
SS-N-B	-	4.6	4.2	4.1	3.0	-
SS-N-C	-	0.7	1.9	1.9	1.4	-
SS-N-D	-	7.1	6.1	3.7	3.8	-
SS-N-E	-	3.6	2.9	3.6	3.2	-
SS-N-F	-	3.8	4.4	4.1	3.4	-
SS-N-G	-	-	-	2.3	-	-
LAG-1(SOLID)	-	-	-	-	137*	-
LAG-1(LIQUID)	-	-	-	-	81	-
LAG-2(LIQUID)	-	-	-	-	10.6	-
UREA TANK	-	-	-	-	1.4	-
SEWER	-	-	-	-	8.1	-
SUMP-1	-	-	-	-	26.3	-

*mg/kg

TABLE D-7

SURFACE WATER CHEMICAL ANALYSES

Well Number	Alkalinity, mg/l 3-81	4-81	5-81	6-81	8-81	12-81
SS-1	366	44	41	45	-	42
SS-1A	-	-	-	-	35	-
SS-2	-	-	390	870	-	-
SS-5	78	192	210	65	-	26
SS-11	30	800	30	28	-	-
SS-12	73	170	161	112	-	33
SS-16	58	62	60	55	-	52
SS-N-A	-	-	-	58	-	-
SS-N-B	-	-	-	60	-	-
SS-N-C	-	-	-	25	-	-
SS-N-D	-	-	-	220	-	-
SS-N-E	-	-	-	55	-	-
SS-N-F	-	-	-	80	-	-
SS-N-G	-	-	-	<1	-	-
LAG-1(SOLID)	-	-	-	-	-	-
LAG-1(LIQUID)	-	-	-	-	4150	-
LAG-2(LIQUID)	-	-	-	-	1210	-
UREA TANK	-	-	-	-	65	-
SEWER	-	-	-	-	85	-
SUMP-1	-	-	-	-	32	-

TABLE D-8

SURFACE WATER CHEMICAL ANALYSES

Well Number	Chromium + 6, mg/l					
	3-81*	4-81	5-81	6-81	8-81	12-81
SS-1	<0.02	<0.01	BDL	BDL	-	BDL
SS-1A	-	-	-	-	BDL	-
SS-2	-	-	0.01	0.03	BDL	-
SS-5	0.18	0.03	0.01	BDL	BDL	BDL
SS-11	0.16	0.01	0.01	BDL	BDL	-
SS-12	0.42	BDL	BDL	BDL	-	BDL
SS-16	<0.02	BDL	BDL	BDL	-	BDL

Detection Limit: 0.01 mg/l

*Total metal - sample acidified

TABLE D-9

SURFACE WATER CHEMICAL ANALYSES

Well Number	Chromium + 3, mg/l					
	3-81	4-81	5-81	6-81	8-81	12-81
SS-1	-	<0.05	<0.04	<0.04	<0.04	<0.04
SS-1A	-	-	-	-	-	-
SS-2	-	-	<0.04	≦0.02	<0.04	-
SS-5	-	<0.05	<0.04	<0.04	<0.04	<0.04
SS-11	-	<0.05	<0.04	<0.04	<0.04	-
SS-12	-	<0.05	<0.04	<0.04	<0.04	<0.04
SS-16	-	<0.05	<0.04	<0.04	<0.04	<0.04

TABLE D-10

SURFACE WATER CHEMICAL ANALYSES

Well Number	Cadmium, mg/l					
	3-81*	4-81	5-81	6-81	8-81	12-81
SS-1	BDL	BDL	BDL	BDL	BDL	BDL
SS-1A	-	-	-	-	-	-
SS-2	-	-	<0.01	BDL	-	-
SS-5	BDL	BDL	BDL	BDL	BDL	BDL
SS-11	BDL	BDL	BDL	BDL	BDL	-
SS-12	BDL	BDL	BDL	BDL	-	BDL
SS-16	BDL	BDL	BDL	BDL	-	BDL

Detection Limit: 0.01 mg/l

Total metal - sample acidified

TABLE D-11

SURFACE WATER CHEMICAL ANALYSES

Well Number	Lead, mg/l 3-81*	4-81	5-81	6-81	8-81	12-81
SS-1	<0.10	<0.10	BDL	BDL	-	BDL
SS-1A	-	-	-	-	BDL	-
SS-2	-	-	BDL	BDL	BDL	-
SS-5	<0.10	<0.10	BDL	BDL	BDL	BDL
SS-11	<0.10	<0.10	BDL	BDL	BDL	-
SS-12	<0.10	<0.10	BDL	BDL	-	BDL
SS-16	<0.10	<0.10	BDL	BDL	-	BDL

Detection Limit: 0.04 mg/l

*Total metal - sample acidified

TABLE D-12

SURFACE WATER CHEMICAL ANALYSES

Well Number	Dissolved Oxygen, mg/l					
	3-81	4-81	5-81	6-81	8-81	12-81
SS-1	-	6.7	8.2	6.4	-	-
SS-1A	-	-	-	-	-	-
SS-2	-	-	-	-	-	-
SS-5	-	10.4	8.5	3.5	-	-
SS-11	-	11.0	2.6	6.2	-	-
SS-12	-	10.4	6.2	6.9	-	-
SS-16	-	9.0	6.0	6.5	-	-
SS-N-A	-	-	-	-	-	-
SS-N-B	-	-	-	-	-	-
SS-N-C	-	-	-	-	-	-
SS-N-D	-	-	-	-	-	-
SS-N-E	-	-	-	-	-	-
SS-N-F	-	-	-	-	-	-
SS-N-G	-	-	-	-	-	-
LAG-1(SOLID)	-	-	-	-	-	-
LAG-1(LIQUID)	-	-	-	-	-	-
LAG-2(LIQUID)	-	-	-	-	-	-
UREA TANK	-	-	-	-	-	-
SEWER	-	-	-	-	-	-
SUMP-1	-	-	-	-	-	-

TABLE D-13

SURFACE WATER CHEMICAL ANALYSES

Well Number	Temperature, °C					
	3-81	4-81	5-81	6-81	8-81	12-81
SS-1	6	7	22	23	24	7
SS-1A	-	-	-	-	23	-
SS-2	-	-	-	-	18	-
SS-5	6	12.5	23	25	28	4
SS-11	10.5	11.5	19	24	26	-
SS-12	8.5	7.5	18	23	25	2.5
SS-16	8	12.5	23	29.5	29	5
SS-N-A	-	-	-	-	-	-
SS-N-B	-	-	-	-	-	-
SS-N-C	-	-	-	-	-	-
SS-N-D	-	-	-	-	-	-
SS-N-E	-	-	-	-	-	-
SS-N-F	-	-	-	-	-	-
SS-N-G	-	-	-	-	-	-
LAG-1(SOLID)	-	-	-	-	-	-
LAG-1(LIQUID)	-	-	-	-	-	-
LAG-2(LIQUID)	-	-	-	26	-	-
UREA TANK	-	-	-	-	-	-
SEWER	-	-	-	-	-	-
SUMP-1	-	-	-	20	-	-

APPENDIX E

ORGANIC CHEMICAL ANALYSES

APPENDIX E
ORGANIC ANALYSIS TECHNIQUES

1.	Volatile Organics	Method 624, Federal Register 12-3-79
2.	Base/Neutral Extractable Organics	Method 625, Federal Register, 12-3-79

TABLE E-1

COMPARISON OF EPA, OLIN AND PIRNIE SAMPLING RESULTS, mg/l

Ground Water

PARAMETER	WELL NUMBER															
	GW-5								GW-10							
	EPA	OLIN	PIRNIE						EPA	OLIN	PIRNIE					
	11-80	11-80	3-81	4-81	5-81	6-81	8-81	12-81	11-80	11-80	3-81	4-81	5-81	6-81	8-81	12-81
Organic																
N-nitrosodiphenyl-amine	BDL	BDL	BDL	-	BDL	-	-	BDL	0.01	BDL	BDL	-	-	-	-	-
DOP	BDL	0.17	0.02	-	0.03	-	-	0.02	0.02	>0.22*	BDL	-	-	-	-	-
Carbon tetra-chloride	BDL	BDL	BDL	-	BDL	-	-	BDL	0.01	BDL	BDL	-	-	-	-	-
Fluoranthene	BDL	BDL	BDL	-	BDL	-	-	BDL	BDL	0.0002	BDL	-	-	-	-	-
Di-n-butyl phthalate	BDL	0.001	BDL	-	BDL	-	-	BDL	BDL	0.001	BDL	-	-	-	-	-
Phenanthrene/ Anthracene	BDL	0.002	BDL	-	BDL	-	-	BDL	BDL	0.005	BDL	-	-	-	-	-

*Due to detector saturation, actual concentrations may be significantly greater.
BDL - Below detection limit

TABLE E-2

COMPARISON OF EPA, OLIN AND PIRNIE SAMPLING RESULTS, mg/l

Surface Water

PARAMETER	SAMPLE NUMBER SS-5							
	EPA	Olin	PIRNIE					
	11-80	11-80	3-81	4-81	5-81	6-81	8-81	12-81
Organic								
N-nitrosodiphenylamine	0.04	BDL	BDL	-	BDL	-	BDL	BDL
DOP	0.1	>0.2*	0.02	-	0.02	-	0.1	BDL
Carbon tetrachloride	BDL	BDL	BDL	-	BDL	-	BDL	BDL
Fluoranthene	BDL	0.001	BDL	-	BDL	-	BDL	BDL
Butyl benzyl phthalate	BDL	0.001	BDL	-	BDL	-	BDL	BDL
Di-n-butyl phtholate	BDL	0.001	BDL	-	BDL	-	BDL	BDL
Phenanthrene/Anthracene	BDL	0.001	BDL	-	BDL	-	BDL	BDL

*Due to detector saturation, actual concentrations may be significantly greater.

BDL - Below detection limit

TABLE E-3

NON-PRIORITY POLLUTANT BASE-NEUTRAL COMPOUNDS

SURFACE WATER

Sample Location	Compound	Concentration*
SS-2	1,1[1] Oxybisbenzene	Low
	Octhanethioicic acid, 5-Hexylester	Low
	2H-Azepin-2-One, Hexahydro-y-Me	Low
SS-5	No Base-Neutrals Detected	
SS-16	1,1[1] Oxybisbenzene	Low
	9H-Carbazole	Low
	2H-1-Benzopyran	Low
	Conoyfolan-16-Carboxylic acid	Low

GROUND WATER

GW-5	No Base-Neutrals Detected	

* Low concentration = <0.05 mg/l
Med. concentration = 0.05 - 0.2 mg/l
High concentration = >0.2 mg/l

TABLE E-4

NON-PRIORITY POLLUTANT VOLATILE COMPOUNDS

SURFACE WATER

Sample Location	Compound	Concentration*
SS-5	Acetone	High
SS-16	Acetone	Med
	2-Butanone	Med
	2-Butanol	Low
	4-Methylpentanone	Med
	2,4,4-Trimethyl-2-Pentene	Low
	4,4-Dimethyl-2-Pentanone	Low
	2,4,4 Trimethyl-1-Pentene	Med
	3,3-Dimethylbutanoic acid	Low
	1,3-Dimethylbenzene	Low
	1,3-Dimethylbenzene	

GROUND WATER

Sample Location	Compound	Concentration*
GW-5	Acetone	Med

* Low concentrations = <0.05 mg/l
Med. concentrations = 0.05 - 0.2 mg/l
High concentrations = >0.2 mg/l

FIGURE E-4

	BENZENE				BROMOFORM				CARBON TETRACHLORIDE			
	3-81	5-81	8-81	12-81	3-81	5-81	8-81	12-81	3-81	5-81	8-81	12-81
GW-1	BDL	-	-	-	BDL	BDL	-	-	BDL	BDL	-	-
GW-2 & 2A	0.011	0.080	-	0.015	BDL	BDL	-	BDL	BDL	BDL	-	BDL
GW-3	BDL	-	-	-	BDL	-	-	-	BDL	-	-	
GW-4	BDL	-	-	BDL	BDL	BDL	-	BDL	BDL	BDL	-	BDL
GW-5	BDL	BDL	-	BDL	BDL	BDL	-	BDL	BDL	BDL	-	BDL
GW-6	BDL	BDL	-	-	0.020	0.015	-	-	BDL	BDL	-	-
GW-7	BDL	BDL	-	-	0.160	0.360	-	-	BDL	BDL	-	-
GW-8	BDL	-	-	-	BDL	BDL	-	-	BDL	BDL	-	-
GW-10	BDL	-	-	-	BDL	-	-	-	BDL	-	-	-
GW-11	BDL	BDL	-		BDL	BDL	-	-	BDL	BDL	-	-
GW-12	BDL	BDL	-	-	BDL	BDL	-	-	BDL	BDL	-	-
GW-13	BDL		-	-	BDL	BDL	-	-	BDL	BDL	-	-
GW-14	BDL	-	-	-	BDL	-	-	-	BDL	-	-	-
GW-15	BDL	BDL	-	-	BDL	BDL	-	-	BDL	BDL	-	-
GW-16	BDL	BDL	-	-	BDL	BDL	-	-	BDL	BDL	-	-
GW-17S	-	-	-	-	-	-	-	-	-	-	-	-
GW-17D	BDL	-	-	-	BDL	BDL	-	-	BDL	BDL	-	-
GW-18S	-	-	-	-	-	-	-	-	-	-	-	-
GW-18D	-	-	-	-	-	-	-	-	-	-	-	-
GW-19S	BDL		-	-	BDL	BDL	-	-	BDL	BDL	-	-
GW-19D	BDL	BDL	-	-	BDL	BDL	-	-	BDL	BDL	-	-
GW-20	BDL	-	-	-	-	BDL	-	-	BDL	BDL	-	-
GW-21	BDL	-	-	-	BDL	-	-	-	BDL	-	-	-
GW-22S	BDL	BDL	-	-	BDL	BDL	-	-	BDL	BDL	-	-
GW-22D	BDL	BDL	-	-	BDL	BDL	-	-	BDL	0.058	-	-
GW-23	-	-	BDL	-	-	-	BDL	-	-	-	BDL	-
GW-24	-	-	-	-	-	-	-	-	-	-	-	-
GW-25	-	-	-	-	-	-	-	-	-	-	-	-
GW-26	-	-	-	-	-	-	-	-	-	-	-	-

	CHLORO-DIBROMOMETHANE				CHLOROETHANE				CHLOROFORM			
	3-81	5-81	8-81	12-81	3-81	5-81	8-81	12-81	3-81	5-81	8-81	12-81
GW-1	BDL	BDL	-	-	BDL	BDL	-	-	BDL	0.010	-	-
GW-2 & 2A	BDL	BDL	-	BDL	BDL	BDL	-	BDL	BDL	BDL	-	BDL
GW-3	BDL	-	-	-	BDL	-	-	-	BDL	-	-	-
GW-4	BDL	BDL	-	BDL	BDL	BDL	-	BDL	BDL	BDL	-	BDL
GW-5	BDL	BDL	-	BDL	BDL	BDL	-	BDL	BDL	BDL	-	BDL
GW-6	BDL	BDL	-	-	BDL	BDL	-	-	BDL	BDL	-	-
GW-7	0.022	0.067	-	-	BDL	BDL	-	-	BDL	0.018	-	-
GW-8	BDL	BDL	-	-	BDL	BDL	-	-	BDL	BDL	-	-
GW-10	BDL	-	-	-	BDL	-	-	-	BDL	-	-	-
GW-11	BDL	BDL	-	-	BDL	BDL	-	-	BDL	BDL	--	-
GW-12	BDL	BDL	-	-	BDL	BDL	-	-	BDL	BDL	-	-
GW-13	BDL	BDL	-	-	BDL	BDL	-	-	BDL	BDL	-	-
GW-14	BDL	-	-	-	BDL	-	-	-	BDL	-	-	-
GW-15	BDL	BDL	-	-	BDL	BDL	-	-	BDL	BDL	-	-
GW-16	BDL	BDL	-	-	BDL	BDL	-	-	BDL	BDL	-	-
GW-17S	-	-	-	-	-	-	-	-	-	-	-	-
GW-17D	BDL	BDL	-	-	BDL	BDL	-	-	BDL	BDL	-	-
GW-18S	-	-	-	-	-	-	-	-	-	-	-	-
GW-18D	-	-	-	-	-	-	-	-	-	-	-	-
GW-19S	BDL	BDL	-	-	BDL	BDL	-	-	BDL	BDL	-	-
GW-19D	BDL	BDL	-	-	BDL	BDL	-	-	BDL	BDL	-	-
GW-20	BDL	BDL	-	-	BDL	BDL	-	-	BDL	BDL	-	-
GW-21	BDL	-	-	-	BDL	-	-	-	BDL	-	-	-
GW-22S	BDL	BDL	-	-	BDL	BDL	-	-	BDL	BDL	-	-
GW-22D	BDL	BDL	-	-	BDL	BDL	-	-	BDL	0.022	-	-
GW-23	-	-	BDL	-	-	-	BDL	-	-	-	BDL	-
GW-24	-	-	-	-	-	-	-	-	-	-	-	-
GW-25	-	-	-	-	-	-	-	-	-	-	-	-
GW-26	-	-	-	-	-	-	-	-	-	-	-	-

	DICHLORO-BROMOMETHANE				1-1-DICHLOROETHANE				1,2-DICHLOROETHANE			
	3-81	5-81	8-81	12-81	3-81	5-81	8-81	12-81	3-81	5-81	8-81	12-81
GW-1	BDL	BDL	-	-	BDL	BDL	-	-	BDL	BDL	-	-
GW-2 & 2A	BDL	BDL	-	BDL	BDL	BDL	-	BDL	0.030	0.011	-	BDL
GW-3	BDL	-	-	-	BDL	-	-	-	BDL	-	-	-
GW-4	BDL	BDL	-	BDL	BDL	BDL	-	BDL	BDL	BDL	-	BDL
GW-5	BDL	BDL	-	BDL	BDL	BDL	-	BDL	BDL	BDL	-	BDL
GW-6	BDL	BDL	-	-	BDL	BDL	-	-	0.075	0.070	-	-
GW-7	BDL	0.022	-	-	BDL	BDL	-	-	0.018	0.046	-	-
GW-8	BDL	-	-	-	BDL	-	-	-	BDL	-	-	-
GW-10	BDL	-	-	-	BDL	-	-	-	BDL	-	-	-
GW-11	BDL	BDL	-	-	BDL	BDL	-	-	0.014	0.017	-	-
GW-12	BDL	BDL	-	-	BDL	BDL	-	-	BDL	BDL	-	-
GW-13	BDL	BDL	-	-	BDL	BDL	-	-	BDL	BDL	-	-
GW-14	BDL	-	-	-	BDL	-	-	-	BDL	-	-	-
GW-15	BDL	BDL	-	-	BDL	BDL	-	-	0.086	0.044	-	-
GW-16	BDL	BDL	-	-	BDL	BDL	-	-	BDL	BDL	-	-
GW-17S	-	-	-	-	-	-	-	-	-	-	-	-
GW-17D	BDL	BDL	-	-	BDL	BDL	-	-	BDL	BDL	-	-
GW-18S	-	-	-	-	-	-	-	-	-	-	-	-
GW-18D	-	-	-	-	-	-	-	-	-	-	-	-
GW-19S	BDL	BDL	-	-	BDL	BDL	-	-	BDL	BDL	-	-
GW-19D	BDL	BDL	-	-	BDL	BDL	-	-	BDL	BDL	-	-
GW-20	BDL	BDL	-	-	BDL	BDL	-	-	BDL	0.0062	-	-
GW-21	BDL	-	-	-	BDL	-	-	-	BDL	-	-	-
GW-22S	BDL	BDL	-	-	BDL	BDL	-	-	BDL	BDL	-	-
GW-22D	BDL	BDL	-	-	BDL	BDL	-	-	BDL	BDL	-	-
GW-23	-	-	BDL	-	-	-	BDL	-	-	-	BDL	-
GW-24	-	-	-	-	-	-	-	-	-	-	-	-
GW-25	-	-	-	-	-	-	-	-	-	-	-	-
GW-26	-	-	-	-	-	-	-	-	-	-	-	-

	ETHYLBENZENE				METHYL CHLORIDE				METHYLENE CHLORIDE			
	3-81	5-81	8-81	12-81	3-81	5-81	8-81	12-81	3-81	5-81	8-81	12-81
GW-1	BDL	BDL	-	-	BDL	BDL	-	-	0.018	BDL	--	-
GW-2 & 2A	BDL	0.036	-	BDL	0.010	BDL	-	BDL	0.014	BDL	-	BDL
GW-3	BDL	-	-	-	BDL	-	-	-	BDL	-	-	-
GW-4	BDL	-	-	BDL	BDL		-	BDL	0.023	BDL	-	2.39
GW-5	BDL	BDL	-	BDL	BDL	BDL	-	BDL	0.081	BDL	-	0.38
GW-6	BDL	BDL	-	-	BDL	BDL	-	-	0.054	0.018	-	-
GW-7	BDL	BDL	-	-	BDL	0.010	-	-	0.073	BDL	-	-
GW-8	BDL	-	-	-	BDL	BDL	-	-	0.034	BDL	-	-
GW-10	BDL	-	-	-	BDL	BDL	-	-	BDL	BDL	-	-
GW-11	BDL	BDL	-	BDL	0.042	0.013	-	BDL	0.042	0.013	-	BDL
GW-12	BDL	BDL	-	-	BDL	BDL	-	-	0.200	BDL	-	-
GW-13	BDL	-	-	-	BDL	BDL	-	-	0.033	BDL	-	-
GW-14	BDL	-	-	-	BDL	-	-	-	0.011	BDL	-	-
GW-15	BDL	BDL	-	-	BDL	BDL	-	-	0.020	BDL	-	-
GW-16	0.290	BDL	-	-	BDL	BDL	-	-	BDL	BDL	-	-
GW-17S	-	-	-	-	-	-	-	-	-	-	-	-
GW-17D	BDL	-	-	-	BDL	BDL	-	-	0.065	BDL	-	-
GW-18S	-	-	-	-	-	-	-	-	-	-	-	-
GW-18D	-	-	-	-	-	-	-	-	-	-	-	-
GW-19S	BDL	-	-	-	BDL	BDL	-	-	0.067	BDL	-	-
GW-19D	BDL	BDL	-	-	BDL	BDL	-	-	0.082	BDL		-
GW-20	BDL	-	-	-	BDL	BDL	-	-	0.018	BDL	-	-
GW-21	BDL	-	-	-	BDL	-	-	-	BDL	-	-	-
GW-22S	BDL	BDL	-	-	BDL	BDL	-	-	BDL	BDL	-	-
GW-22D	BDL	BDL	-	-	BDL	BDL	-	-	0.019	BDL	-	-
GW-23	-	-	BDL	-	-	-	BDL	-	-	-	BDL	-
GW-24	-	-	-	-	-	-	-	-	-	-	-	-
GW-25	-	-	-	-	-	-	-	-	-	-	-	-
GW-26	-	-	-	-	-	-	-	-	-	-	-	-

	1,1,2,2-TETRACHLORO-ETHANE				TOLUENE				1,1,1-TRICHLORO-ETHANE			
	3-81	5-81	8-81	12-81	3-81	5-81	8-81	12-81	3-81	5-81	8-81	12-81
GW-1	BDL	BDL	-	-	BDL	-	-	-	BDL	0.0031	-	-
GW-2 & 2A	BDL	BDL	-	BDL	0.016	0.061	-	0.012	BDL	BDL	-	BDL
GW-3	BDL	-	-	-		-	-	-	BDL	-	-	-
GW-4	BDL	BDL	-	BDL	BDL		-	BDL	BDL	0.001	-	BDL
GW-5	BDL	BDL	-	BDL	BDL	BDL	-	BDL	BDL	BDL	-	BDL
GW-6	BDL	BDL	-	-	0.034	0.010	-	-	BDL	BDL	-	-
GW-7	BDL	BDL	-	-	0.014	0.036	-	-	BDL	BDL	-	-
GW-8	BDL	BDL	-	-	BDA	-	-	-	BDL	BDL	-	-
GW-10	BDL		-	-	BDL	-	-	-	BDL	BDL	-	-
GW-11	BDL	BDL	-	BDL	BDL	BDL	-	BDL	BDL	BDL	-	BDL
GW-12	BDL	BDL	-	-	BDL	BDL	-	-	BDL	BDL	-	-
GW-13	BDL	BDL	-	-	BDL	BDL	-	-	BDL	BDL	-	-
GW-14	BDL	-	-		BDL	-	-	-	BDL	-	-	-
GW-15	BDL	BDL	-	-	BDL	BDL	-	-	BDL	BDL	-	-
GW-16	0.065	BDL	-	-	0.650	BDL	-	-	BDL	BDL	-	-
GW-17S	-	-	-	-	-	-	-	-	-	-	-	-
GW-17D	BDL	BDL	-	-	BDL	-	-	-	BDL	BDL	-	-
GW-18S	-	-	-	-	-	-	-	-	-	-	-	-
GW-18D	-	-	-	-	-	-	-	-	-	-	-	-
GW-19S	BDL	BDL	-	-	BDL	-	-	-	BDL	BDL	-	-
GW-19D	BDL	BDL	-	-	0.050	0.059	-	-	BDL	BDL	-	-
GW-20	BDL	BDL	-	-	BDL	-	-	-	BDL	BDL	-	-
GW-21	BDL	-	-	-	BDL	-	-	-	BDL	-	-	-
GW-22S	BDL	BDL	-	-	0.010	BDL	-	-	BDL	BDL	-	-
GW-22D	BDL	BDL	-	-	0.010	0.010	-	-	BDL	BDL	-	-
GW-23	-	-	BDL	-	-	-	BDL	-	-	-	BDL	-
GW-24	-	-	-	-	-	-	-	-	-	-	-	-
GW-25	-	-	-	-	-	-	-	-	-	-	-	-
GW-26	-	-	-	-	-	-	-	-	-	-	-	-

NOTES:

* Quantitated from secondary ion.
□ Indistinguishable isomers.
▲ Concentration estimated, quantitation ion satur
BDL Below Detectable Limit
- Not sampled

OLIN CHEMICALS GROUP
WILMINGTON, MASS.

PRIORITY POLLUTANT VOLATILES IN GROUND WATER, MG/L

MALCOLM PIRNIE, INC.

FIGURE E-5

	BENZENE				BROMOFORM				CARBON TETRACHLORIDE				CHLORO-DIBROMOMETHANE				CHLOROETHANE			
	3-81	5-81	8-81	12-81	3-81	5-81	8-81	12-81	3-81	5-81	8-81	12-81	3-81	5-81	8-81	12-81	3-81	5-81	8-81	12-81
SS-1	BDL	BDL	-	BDL	BDL	BDL	-	BDL	BDL	BDL	-	BDL	BDL	BDL	-	BDL	0.013	0.015	-	BDL
SS-1A	-	-	BDL	-	-	-	BDL	-	-	-	BDL	-	-	-	BDL	-	-	-	0.014	-
SS-2	-	-	BDL	-	-	-	BDL	-	-	-	BDL	-	-	-	BDL	-	-	-	BDL	-
SS-5	BDL	BDL	-	BDL	BDL	BDL	-	BDL	BDL	BDL	-	BDL	BDL	BDL	-	BDL	BDL	BDL	-	BDL
SS-11	BDL	BDL	-	-	BDL	BDL	-	-	BDL	BDL	-	-	BDL	BDL	-	-	BDL	BDL	-	-
SS-12	BDL	BDL	-	BDL	0.018	BDL	-	BDL	BDL	BDL	-	BDL	BDL	BDL	-	BDL	BDL	BDL	-	BDL
SS-16	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
LAG.L.	-	-	BDL	-	-	-	BDL	-	-	-	BDL	-	-	-	BDL	-	-	-	BDL	-

	CHLOROFORM				DICHLOROBROMOMETHANE				1-1-DICHLOROETHANE				1,2-DICHLOROETHANE			
	3-81	5-81	8-81	12-81	3-81	5-81	8-81	12-81	3-81	5-81	8-81	12-81	3-81	5-81	8-81	12-81
SS-1	BDL	BDL	-	BDL	BDL	BDL	-	BDL	0.010	0.018	-	BDL	BDL	BDL	-	BDL
SS-1A	-	-	BDL	-	-	-	BDL	-	-	-	0.026	-	-	-	BDL	-
SS-2	-	-	BDL	-	-	-	BDL	-	-	-	BDL	-	-	-	BDL	-
SS-5	BDL	BDL	-	BDL	BDL	BDL	-	BDL	BDL	BDL	-	BDL	BDL	BDL	-	BDL
SS-11	BDL	BDL	-	-	BDL	BDL	-	-	BDL	BDL	-	-	BDL	BDL	-	-
SS-12	BDL	BDL	-	BDL	BDL	BDL	-	BDL	BDL	BDL	-	BDL	BDL	BDL	-	BDL
SS-16	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
LAG.L.	-	-	BDL	-	-	-	BDL	-	-	-	BDL	-	-	-	0.039	-

	ETHYLBENZENE				METHYL CHLORIDE				METHYLENE CHLORIDE				1,1,2,2-TETRACHLORO-ETHANE			
	3-81	5-81	8-81	12-81	3-81	5-81	8-81	12-81	3-81	5-81	8-81	12-81	3-81	5-81	8-81	12-81
SS-1	BDL	BDL	-	BDL	BDL	BDL	-	BDL	0.017	BDL	-	BDL	BDL	BDL	-	BDL
SS-1A	-	-	BDL	-	-	-	BDL	-	-	-	BDL	-	-	-	BDL	-
SS-2	-	-	BDL	-	-	-	BDL	-	-	-	BDL	-	-	-	BDL	-
SS-5	BDL	BDL	-	BDL	BDL	BDL	-	BDL	0.072	BDL	-	0.272	BDL	BDL	-	BDL
SS-11	BDL	BDL	-	-	BDL	BDL	-	-	0.022	BDL	-		BDL	BDL	-	-
SS-12	BDL	BDL	-	BDL	BDL	BDL	-	BDL	0.015	BDL	-	0.336	BDL	BDL	-	BDL
SS-16	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.019	BDL	BDL	BDL	BDL	BDL	BDL	BDL
LAGOON LIQUID	-	-	BDL	-	-	-	BDL	-	-	-	0.023	-	-	-	BDL	-

	TOLUENE				1,1,1-TRICHLORO-ETHANE				TRICHLOROETHYLENE			
	3-81	5-81	8-81	12-81	3-81	5-81	8-81	12-81	3-81	5-81	8-81	12-81
SS-1	0.70*	0.550*	-	0.310	0.017	0.026	-	BDL	BDL	BDL	-	BDL
SS-1A	-	-	0.270	-	-	-	0.047	-	-	-	BDL	-
SS-2	-	-	BDL	-	-	-	BDL	-	-	-	BDL	-
SS-5	BDL	BDL	-	BDL	BDL	BDL	-	BDL	BDL	BDL	-	BDL
SS-11	BDL	BDL	-		BDL	BDL	-	-	BDL	BDL	-	BDL
SS-12	BDL	BDL	-	BDL	BDL	BDL	-	BDL	BDL	BDL	-	BDL
SS-16	0.180	0.082	BDL	0.043	0.03	0.033	0.020	BDL	BDL	BDL	BDL	0.053
LAGOON LIQUID	-	-	0.025	-	-	-	BDL	-				

PRIORITY POLLUTANT VOLATILES IN SURFACE WATER, MG/L

	ACENAPHTYLENE				ANTHRACENE[a]				BIS (2-ETHYLHEXYL) PHTHALATE (DOP)				4-BROMOPHENYL PHENYL ETHER				BUTYL BENZYL PHTHALATE			
	3-81	5-81	8-81	12-81	3-81	5-81	8-81	12-81	3-81	5-81	8-81	12-81	3-81	5-81	8-81	12-81	3-81	5-81	8-81	12-81
SS-1	BDL	-	-	BDL	BDL	-	-	BDL	BDL	-	-	BDL	BDL	-	-	BDL	BDL	-	-	BDL
SS-1A	-	-	BDL	-	-	-	BDL	-	-	-	BDL	-	-	-	BDL	-	-	-	BDL	-
SS-2	-	-	BDL	--	-	-	BDL	-	-	-	0.025	-	-	-	BDL	-	-	BDL	-	-
SS-5	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.020	0.022	0.100	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
SS-11	BDL	-	-	-	BDL	-	-	-	0.010	-	-	-	BDL	-	-	-	BDL	-	-	-
SS-12	BDL	BDL	-	BDL	BDL	BDL	-	BDL	BDL	BDL	-	BDL	BDL	BDL	-	BDL	BDL	BDL	-	BDL
SS-16	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.098	1.700*	0.095	0.11	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
LAGOON LIQUID	-	-	BDL	-	-	-	BDL	-	-	-	0.320	--	-	-	BDL	-	-	-	BDL	-

	DI-N-BUTYL PHTHALATE				FLUORENE				NAPHTHALENE				"N-NITROSO-DIPHENYLAMINE" **			
	3-81	5-81	8-81	12-81	3-81	5-81	8-81	12-81	3-81	5-81	8-81	12-81	3-81	5-81	8-81	12-81
SS-1	BDL	-	-	BDL	BDL	-	-	BDL	BDL	--	-	BDL	BDL	-	-	BDL
SS-1A	-	-	BDL	-	-	-	BDL	-	-	-	-	BDL	-	-	-	BDL
SS-2	-	BDL	-	-	-	-	BDL	-	-	-	BDL	-	-	-	BDL	-
SS-5	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
SS-11	BDL	-	-	-	BDL	-	-	-	BDL	-	-	-	BDL	-	-	-
SS-12	BDL	BDL	-	BDL	BDL	BDL	-	BDL	BDL	BDL	-	BDL	BDL	BDL	-	BDL
SS-16	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.052	0.150	BDL	0.190
LAGOON LIQUID	-	-	BDL	-	-	-	BDL	-	-	-	BDL	-	-	-	0.037	-

	PHENANTHRENE[a]				DIOCTYL-DIPHENYLAMINE			
	3-81	5-81	8-81	12-81	3-81	5-81	8-81	12-81
SS-1	BDL	-	-	BDL	BDL	-	-	BDL
SS-1A	-	-	BDL	-	-	-	BDL	-
SS-2	-	-	BDL	-	-	-	BDL	-
SS-5	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
SS-11	BDL	-	-	-	BDL	-	-	-
SS-12	BDL	BDL	-	BDL	BDL	BDL	-	BDL
SS-16	BDL	BDL	BDL		BDL	0.023	-	
LAGOON LIQUID	-	-	BDL	-	-	-	-	-

NOTES:

- * Quantitated from secondary ion.
- □ Indistinguishable isomers.
- ▲ Concentration estimated, quantitationiion saturated.
- BDL Below Detectable Limit
- \- Not sampled
- ** Detected as Diphenylamine (Approximately 20% N-Nitrosodiphenylamine)

OLIN CHEMICALS GROUP
WILMINGTON, MASS.

PRIORITY POLLUTANT BASE/NEUTRALS IN SURFACE WATER, MG/L

FIGURE E-6

	ACENAPHTYLENE				ANTHRACENE □				BIS (2-ETHYLHEXYL) PHTHALATE (DOP)			
	3-81	5-81	8-81	12-81	3-81	5-81	8-81	12-81	3-81	5-81	8-81	12-81
GW-1	BDL	BDL	-	-	BDL	BDL	-	-	0.01	0.026	-	-
GW-2 & 2A	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	10.0*	0.200	0.053	36.0*
GW-3	BDL	BDL	-	-	BDL	BDL	-	-	0.05	0.025	-	-
GW-4	BDL	-	-		BDL	BDL	-		0.073	-	-	0.017
GW-5	BDL	BDL	-		BDL	BDL	-		0.016	0.027	-	0.019
GW-6	BDL	-	-	-	BDL	-	-	-	BDL	-	-	-
GW-7	BDL	BDL	BDL	-	BDL	BDL	BDL	-	0.013	0.178	0.030	-
GW-8	BDL	-	-	-	BDL	-	-	-	BDL	-	-	-
GW-10	BDL	-	-	-	BDL	-	-	-	BDL	-	-	-
GW-11	BDL	BDL	BDL	BDL	BDL	0.033	0.017	BDL	BDL	BDL	0.017	0.017
GW-12	BDL	-	-	-	BDL	-	-	-	BDL	-	-	-
GW-13	BDL	BDL	BDL	-	BDL	BDL	BDL	-	0.240*	0.110	0.250	-
GW-14	BDL	BDL	BDL	-	BDL	BDL	BDL	-	0.260*	0.130	0.045	-
GW-15	BDL	BDL	-	-	BDL	BDL	-	-	0.062	0.099	-	-
GW-16	BDL	BDL	BDL	-	BDL	BDL	BDL	-	0.044	>1.00▲	9.400*	-
GW-17S	-	BDL	-	-	-	BDL	-	-	-	0.018	-	-
GW-17D	BDL	BDL	BDL	-	BDL	BDL	BDL	-	0.180	0.051	0.200	-
GW-18S	-	-	-	-	-	-	-	-	-	-	-	-
GW-18D	-	-	-	-	-	BDL	BDL	-	-	0.069	0.270	-
GW-19S	BDL	BDL	BDL	-	BDL	BDL	BDL	-	0.060	0.140	0.310	-
GW-19D	BDL	-	-	-	BDL	-	-	-	BDL	-	-	-
GW-20	BDL	BDL	BDL	-	BDL	BDL	BDL	-	0.011	0.160	0.091	-
GW-21	0.036	BDL	BDL	-	0.028	BDL	BDL	-	0.026	0.083	0.050	-
GW-22S	BDL	BDL	BDL	-	BDL	BDL	BDL	-	1.90	2.50*	0.590	-
GW-22D	BDL	BDL	BDL	-	BDL	BDL	BDL	-	0.016	0.170	0.074	-
GW-23	-	-	BDL	-	-	-	BDL	-	-	-	1.70*	-
GW-24	-	-	-	-	-	-	-	-	-	-	-	-
GW-25	-	-	-	-	-	-	-	-	-	-	-	-
GW-26	-	-	-	-	-	-	-	-	-	-	-	-

	4-BROMOPHENYL PHENYL ETHER				BUTYL BENZYL PHTHALATE				DI-N-BUTYL PHTHALATE			
	3-81	5-81	8-81	12-81	3-81	5-81	8-81	12-81	3-81	5-81	8-81	12-81
GW-1	0.010	0.025	-	-	BDL	BDL	-	-	BDL	BDL	-	-
GW-2 & 2A	BDL	BDL	BDL	BDL	0.009	0.043	BDL		0.029	0.020	0.016	BDL
GW-3	BDL	BDL	-	-	BDL	BDL	-	-	BDL	BDL	-	-
GW-4	BDL	-	-		BDL	-	-		BDL	-	-	
GW-5	BDL	BDL	-	BDL	BDL	BDL	-	BDL	BDL	BDL	-	BDL
GW-6	BDL	-	-	-	BDL	-	-	-	BDL	-	-	-
GW-7	BDL	0.011	BDL	-	BDL	0.012	BDL	-	BDL	BDL	BDL	-
GW-8	BDL	-	-	-	BDL	-	-	-	BDL	-	-	-
GW-10	BDL	-	-	-	BDL	-	-	-	BDL	-	-	-
GW-11	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
GW-12	BDL	-	-	-	BDL	-	-	-	BDL	-	-	-
GW-13	BDL	BDL	BDL	-	0.018	BDL	BDL	-	BDL	BDL	BDL	-
GW-14	BDL	BDL	BDL	-	BDL	BDL	BDL	-	BDL	BDL	BDL	
GW-15	BDL	BDL	-	-	BDL	BDL	-	-	BDL	BDL	-	-
GW-16	BDL	BDL	BDL	-	BDL	BDL	BDL	-	0.170*	BDL	0.013	-
GW-17S	-	BDL	-	-	-	BDL	-	-	-	BDL	-	-
GW-17D	BDL	BDL	BDL	-	0.028	BDL	BDL	-	BDL	BDL	BDL	-
GW-18S	-	-	-	-	-	-	-	-	-	-	-	-
GW-18D	-	-	BDL	-	-	BDL	BDL	-	-	BDL	BDL	-
GW-19S	BDL	BDL	BDL	-	BDL	BDL	BDL	-	BDL	BDL	BDL	-
GW-19D	BDL	-	-	-	BDL	-	-	-	BDL	-	-	-
GW-20	BDL	BDL	BDL	-	BDL	BDL	BDL	-	BDL	BDL	BDL	-
GW-21	BDL	BDL	BDL	-	BDL	BDL	BDL	-	BDL	BDL	BDL	-
GW-22S	BDL	BDL	BDL	-	BDL	BDL	BDL	-	BDL	BDL	BDL	-
GW-22D	BDL	BDL	BDL	-	BDL	BDL	BDL	-	BDL	BDL	BDL	-
GW-23	-	-	BDL	-	-	-	BDL	-	-	-	BDL	-
GW-24	-	-	-	-	-	-	-	-	-	-	-	-
GW-25	-	-	-	-	-	-	-	-	-	-	-	-
GW-26	-	-	-	-	-	-	-	-	-	-	-	-

	FLUORENE				NAPHTHALENE				N-NITROSO-DIPHENYLAMINE**			
	3-81	5-81	8-81	12-81	3-81	5-81	8-81	12-81	3-81	5-81	8-81	12-81
GW-1	BDL	BDL	-	-	BDL	BDL	-	-	BDL	BDL	-	-
GW-2 & 2A	BDL	BDL	BDL		BDL	BDL	BDL	BDL	10.0*	>5.0*	BDL	11.0
GW-3	BDL	BDL	-	-	BDL	BDL	-	-	BDL	BDL	-	-
GW-4	BDL	-	-		BDL	-	-		BDL	-	-	
GW-5	BDL	BDL	-	BDL	BDL	BDL	-	BDL	BDL	BDL	-	BDL
GW-6	BDL	BDL	-	-	BDL	-	-	-	BDL	-	-	-
GW-7	BDL	BDL	BDL	-	BDL	BDL	BDL	-	BDL	BDL	BDL	-
GW-8	BDL	-	-	-	BDL	-	-	-	BDL	-	-	-
GW-10	BDL	-	-	-	BDL	-	-	-	BDL	-	-	-
GW-11	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.059	0.035	0.093	BDL
GW-12	BDL	-	-	-	BDL	-	-	-	BDL		-	-
GW-13	BDL	BDL	BDL	-	BDL	BDL	BDL	-	0.67*	0.025	0.018	-
GW-14	BDL	BDL	BDL	-	BDL	BDL	BDL	-	BDL	0.068	BDL	-
GW-15	BDL	BDL	-	-	BDL	BDL	-	-	BDL	BDL	-	-
GW-16	BDL	BDL	BDL	-	BDL	BDL	BDL	-	0.340	BDL	0.067	-
GW-17S	-	BDL	-	-	-	BDL	-	-	-	BDL	-	-
GW-17D	BDL	BDL	BDL	-	BDL	BDL	BDL	-	BDL	BDL	0.029	-
GW-18S	-	-	-	-	-	-	-	-	-	-	-	-
GW-18D	--	BDL	BDL	-	-	BDL	BDL	-	-	BDL	BDL	-
GW-19S	BDL	BDL	BDL	-	BDL	BDL	BDL	-	BDL	BDL	BDL	-
GW-19D	BDL	-	-	-	BDL	-	-	-	BDL	-	-	-
GW-20	BDL	BDL	BDL	-	BDL	BDL	BDL	-	BDL	BDL	BDL	-
GW-21	0.016	BDL	BDL	-	0.290	BDL	BDL	-	BDL	BDL	BDL	-
GW-22S	BDL	BDL	BDL	-	BDL	BDL	BDL	-	BDL	0.048	BDL	-
GW-22D	BDL	BDL	BDL	-	BDL	BDL	BDL	-	BDL	0.036	0.017	-
GW-23	-	-	BDL	-	-	-	BDL	-	-	-	2.90*	-
GW-24	-	-	-	-	-	-	-	-	-	-	-	-
GW-25	-	-	-	-	-	-	-	-	-	-	-	-
GW-26	-	-	-	-	-	-	-	-	-	-	-	-

	PHENANTHRENE □				DIOCTYL-DIPHENYLAMINE			
	3-81	5-81	8-81	12-81	3-81	5-81	8-81	12-81
GW-1	BDL	BDL	-	-	BDL	BDL	--	-
GW-2 & 2A	BDL	BDL	BDL	BDL	10	2.0*	-	-
GW-3	BDL	BDL	-	-	BDL	BDL	-	-
GW-4	BDL	-	-		BDL	-	-	-
GW-5	BDL	BDL	-	BDL	BDL	BDL	-	-
GW-6	BDL	-	-	-	BDL	-	-	-
GW-7	BDL	BDL	BDL	-	BDL	BDL	BDL	-
GW-8	BDL	-	-	-	BDL	-	-	-
GW-10	BDL	-	-	-	BDL	-	-	-
GW-11	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
GW-12	BDL	-	-	-	BDL	-	-	-
GW-13	BDL	BDL	BDL	-	1.60	0.440		-
GW-14	BDL	BDL	-	-	0.790	0.820*		-
GW-15	BDL	BDL	-	-	0.075	0.030		-
GW-16	BDL	BDL	BDL	-	14.0	>1.00▲		-
GW-17S	-	BDL	-	-	-	BDL	-	-
GW-17D	BDL	BDL	BDL	-	0.027	0.021		-
GW-18S	-	-	-	-	-	-	-	-
GW-18D	-	BDL	BDL	-	-	BDL	BDL	-
GW-19S	BDL	BDL	BDL	--	BDL	0.013		-
GW-19D	BDL	-	-	-	BDL	-	-	-
GW-20	BDL	BDL	BDL	-	BDL	BDL	BDL	-
GW-21	0.020	BDL	BDL	-	BDL	BDL	BDL	-
GW-22S	BDL	BDL	BDL	-	0.073	0.092		-
GW-22D	BDL	BDL	BDL	-	0.019	0.071		-
GW-23	-	-	BDL	-	-	-		-
GW-24	-	-	-	-	--	-	-	-
GW-25	-	-	-	-	-	-	-	-
GW-26	-	-	-	-	-	-	-	-

NOTES:

- * Quantitated from secondary ion.
- □ Indistinguishable isomers.
- ▲ Concentration estimated, quantitation ion saturated.
- BDL Below Detectable Limit
- \- Not sampled
- ** Detected as Diphenylamine (Approximately 20% N-Nitrosodiphenylamine)

OLIN CHEMICALS GROUP
WILMINGTON, MASS.

PRIORITY POLLUTANT BASE/NEUTRALS IN GROUND WATER, MG/L

APPENDIX F

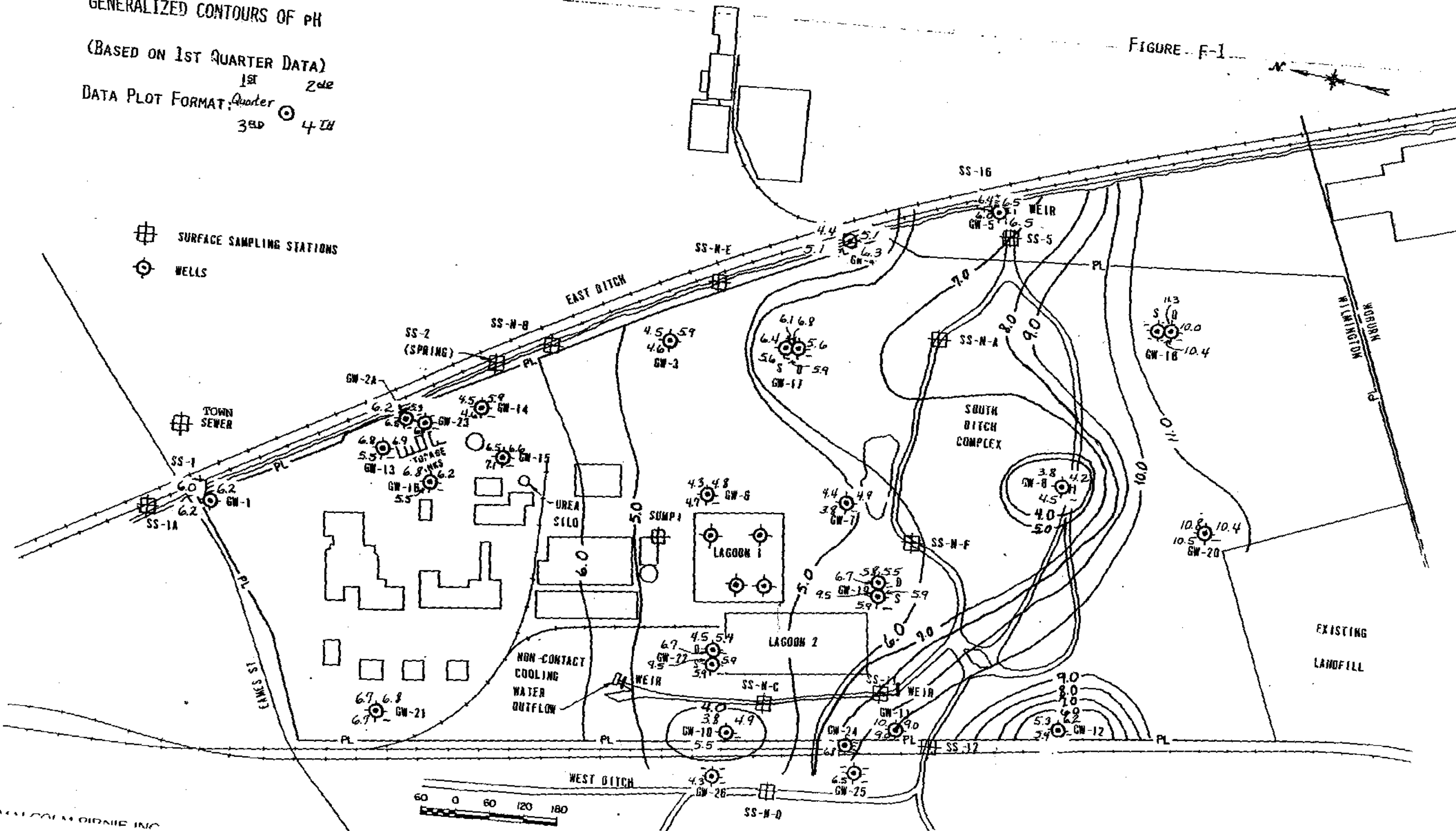
CONTOUR MAPS

GENERALIZED CONTOURS OF pH

(BASED ON 1ST QUARTER DATA)

DATA PLOT FORMAT: 1st Quarter, 2nd, 3rd, 4th

FIGURE F-1



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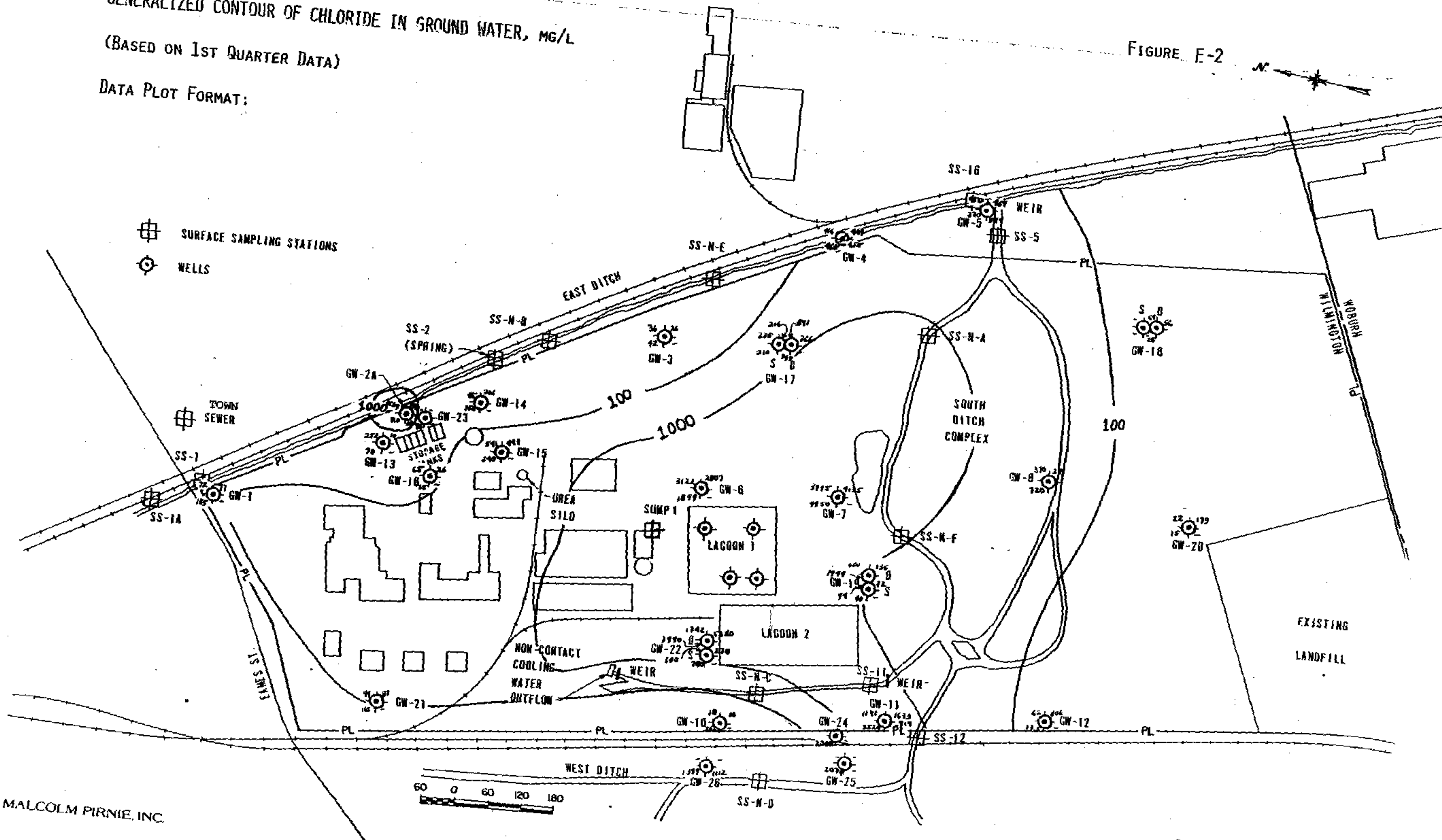
GENERALIZED CONTOUR OF CHLORIDE IN GROUND WATER, MG/L

(BASED ON 1ST QUARTER DATA)

DATA PLOT FORMAT:

FIGURE E-2



MALCOLM PIRNIE, INC.

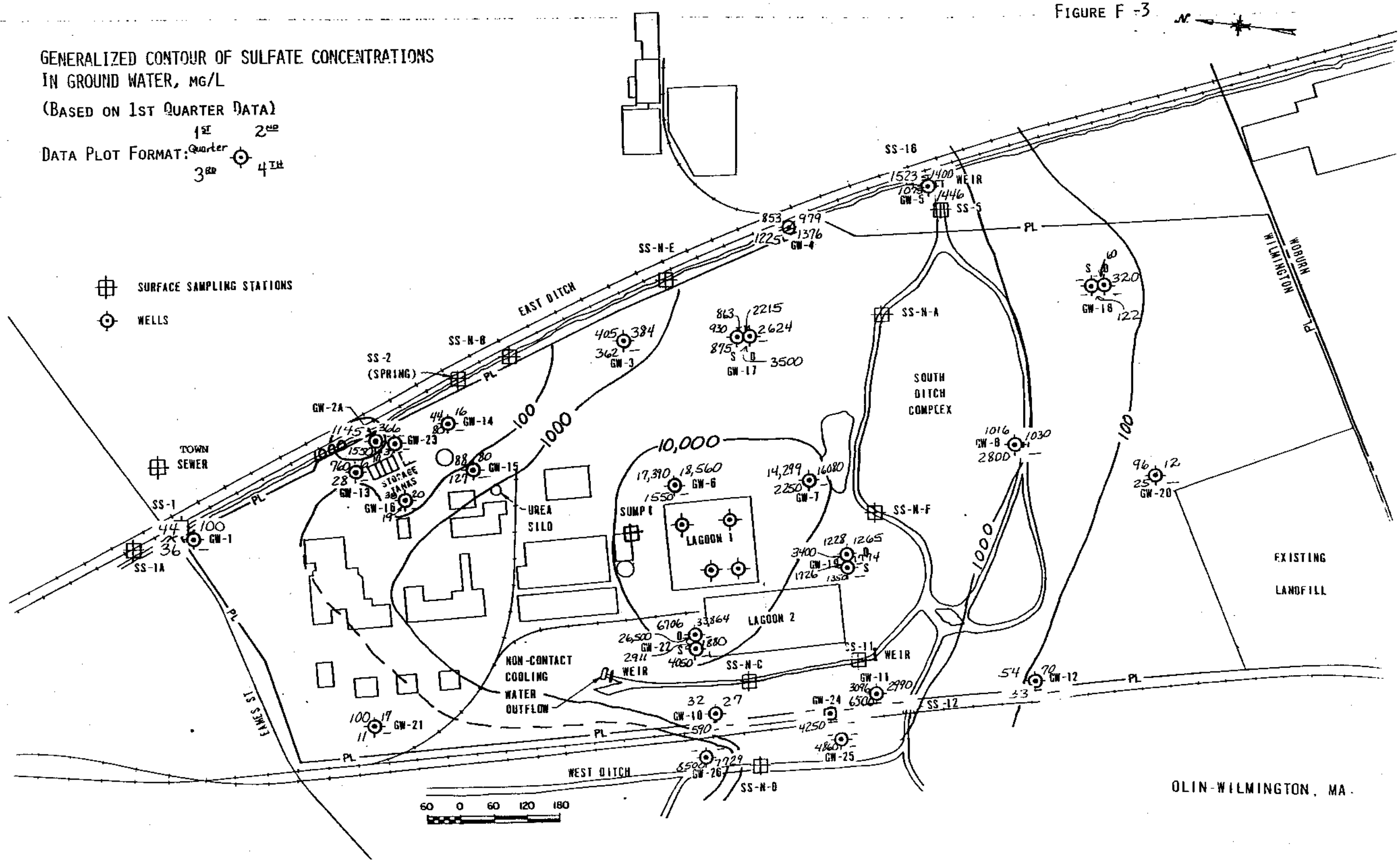
OLIN-WILMINGTON, MA.

FIGURE F-3

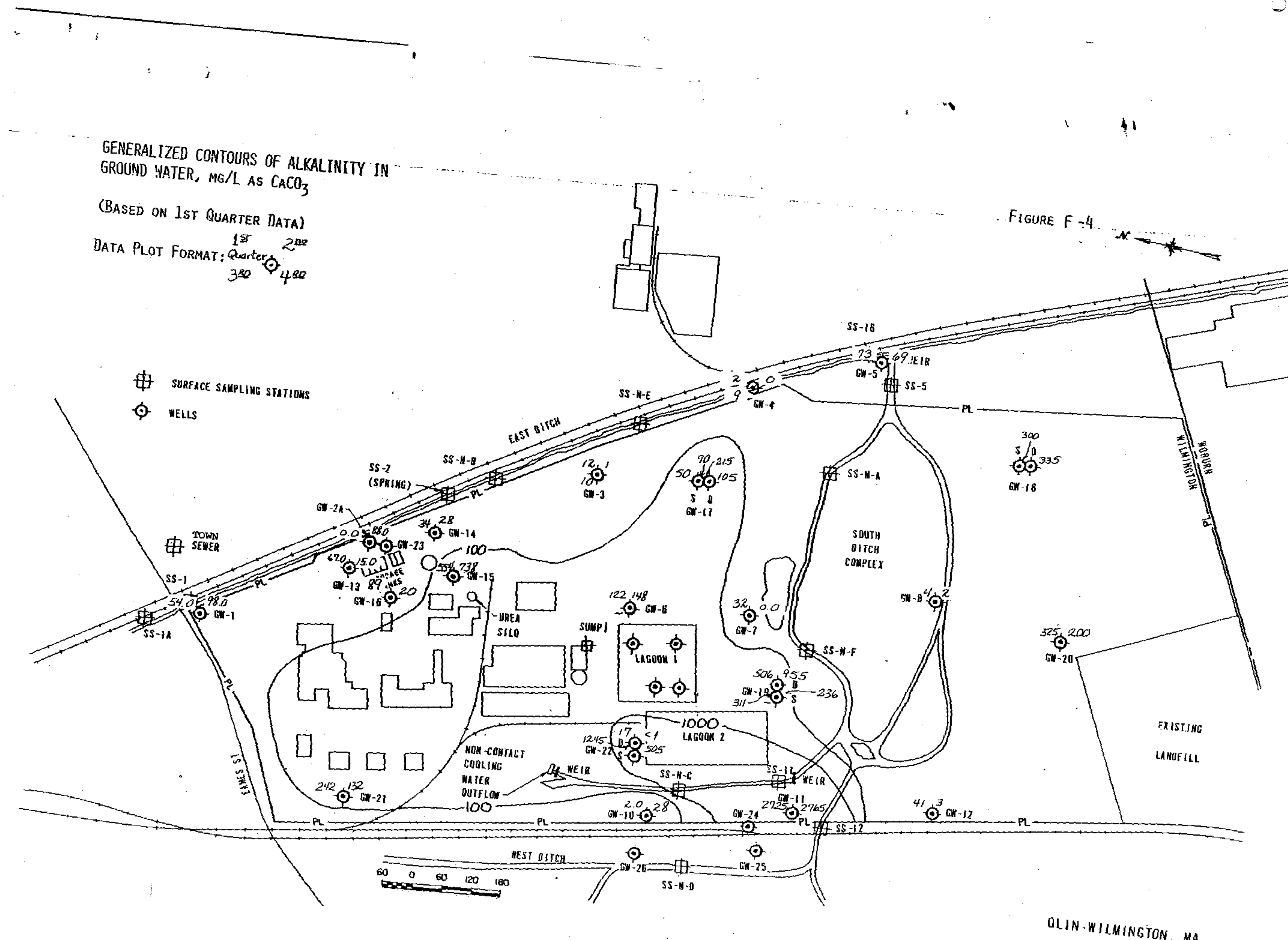
GENERALIZED CONTOUR OF SULFATE CONCENTRATIONS IN GROUND WATER, MG/L

(BASED ON 1ST QUARTER DATA)

DATA PLOT FORMAT: 1ST Quarter, 2ND, 3RD, 4TH



OLIN-WILMINGTON, MA.



GENERALIZED CONTOURS OF ALKALINITY IN GROUND WATER, MG/L AS $CaCO_3$

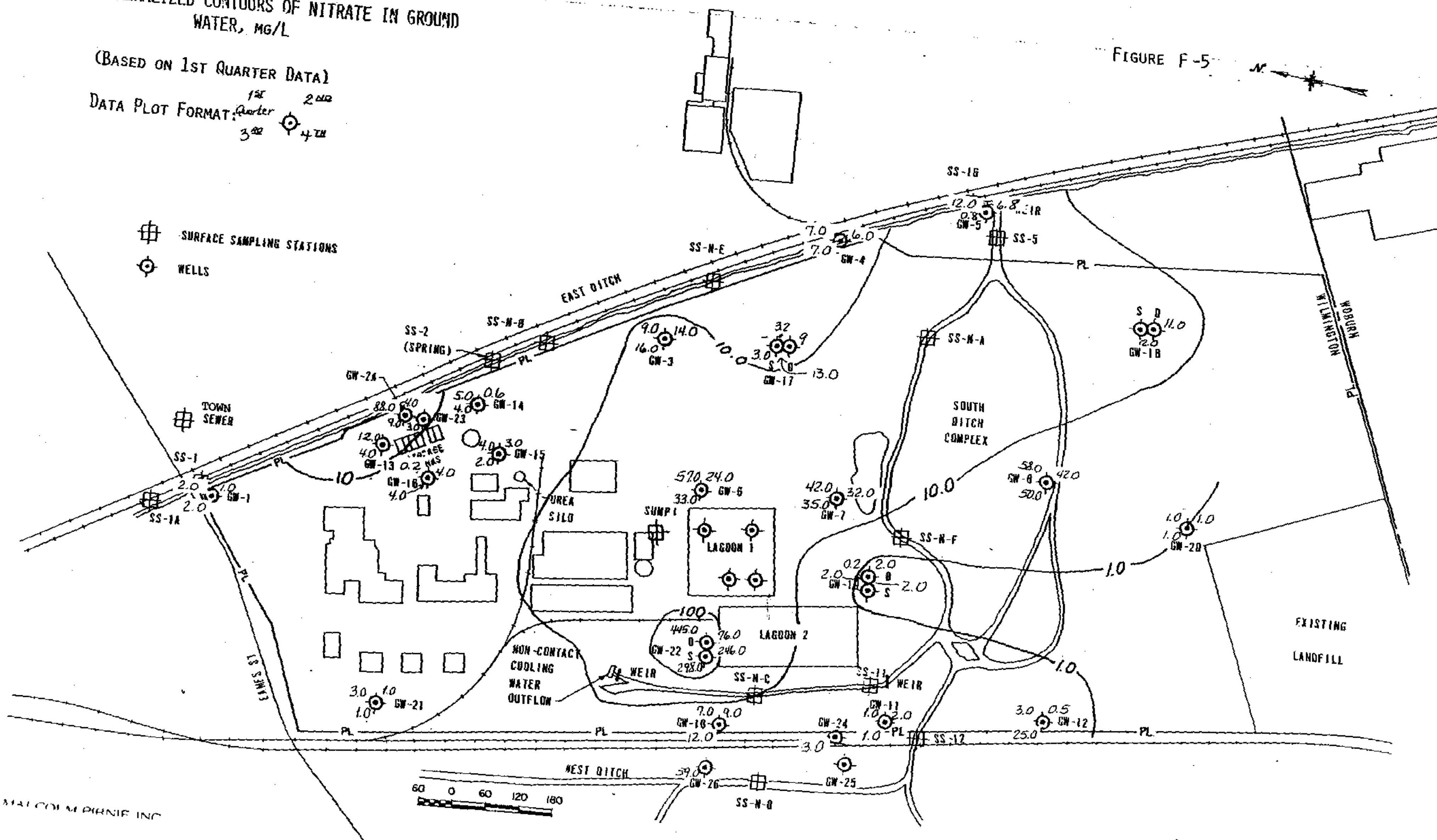
(BASED ON 1ST QUARTER DATA)

FIGURE F-4

GENERALIZED CONTOURS OF NITRATE IN GROUND WATER, MG/L

(BASED ON 1ST QUARTER DATA)

FIGURE F-5



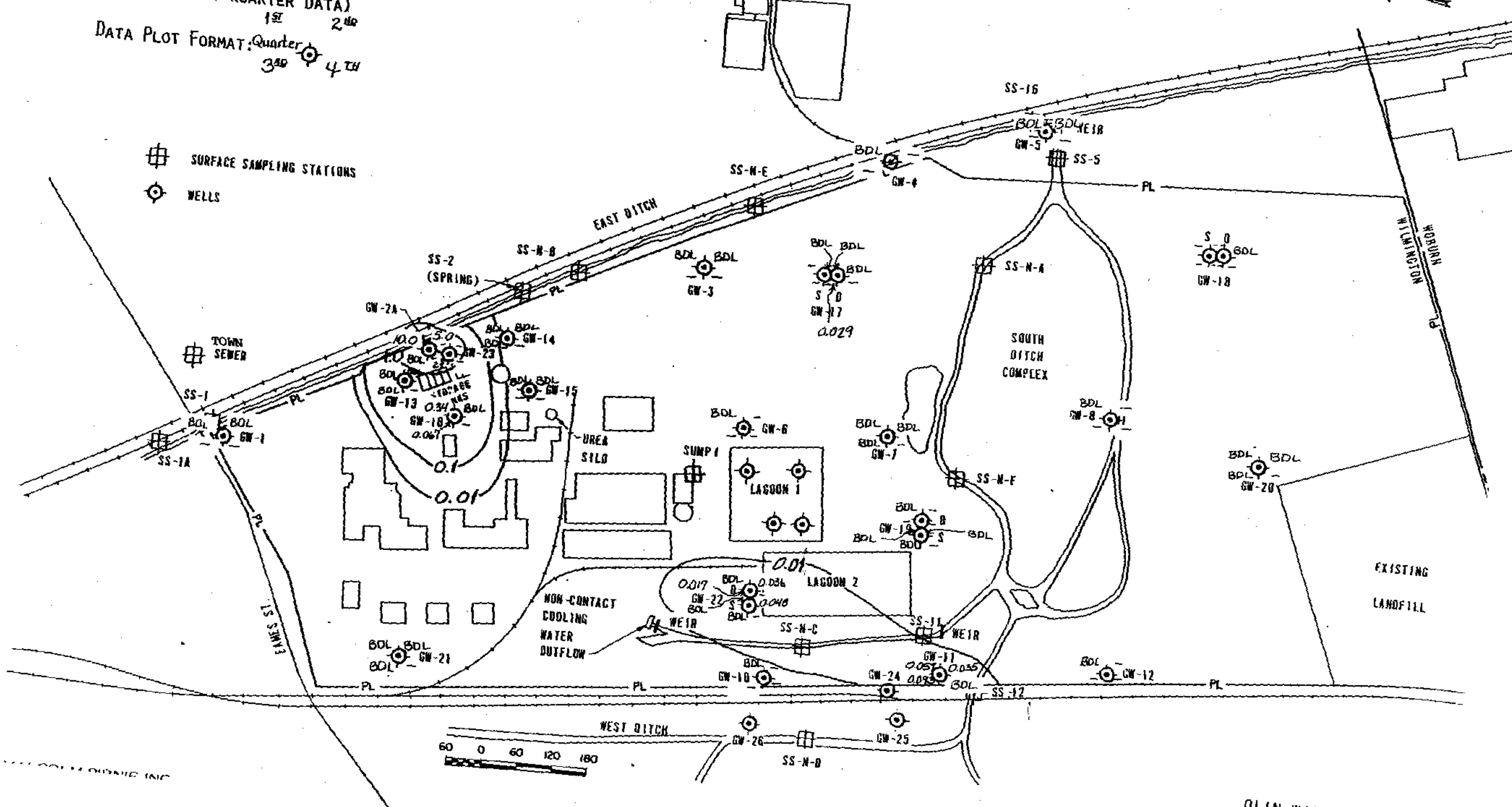
MALCOLM PIRNIE INC

OLIN-WILMINGTON, MA.

GENERALIZED CONTOURS OF N-NITROSODIPHENYLAMINE, IN GROUND WATER, MG/L

(BASED ON 1ST QUARTER DATA)

FIGURE F-6



OLIN-WILMINGTON, MA.